JPRS 75324

18 March 1980

East Europe Report

SCIENTIFIC AFFAIRS

No. 665

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CURRENT, FUTURE DEVELOPMENT OF AUTOMATED SYSTEMS SURVEYED

East Berlin MESSEN-STEUERN-REGELN in German Vol 22 No 10, Oct 79
pp 563-574

/Article by Dr. P. Neumann, engineer, VEB Wilhelm Pieck Instrument and Regulator Works, Teltow: "Current Status of Modern Automation Systems and Some Conclusions for Further Development"/

/Text/ 0. Introduction

In the 30 years' history of the GDR, the technology of automation occupies an important position, since it is an important factor in the growth of the output of our national economy. Its position is documented by the stormy development of the BMSR (Industrial Measuring, Control, and Regulating) system construction. One characteristic process in this connection is the development of the VEB Instrument and Regulator Works Wilhelm Pieck, Teltow - central system construction of the BMSR technology.

The following figures make clear the development of this enterprise:

Its employees have increased about 15-fold
Its industrial goods production has increased about 58-fold
Sales have increased about 100-fold.

During these 30 years, it is not only the quantitative requirements that have grown and been met satisfactorily, but qualitative requirements have also risen enormously, and consequently also the multiplicity of solutions in terms of automated devices and systems.

Viewed on a world scale, what needs must our automation industry meet at the present time, and what complex of solutions exist?

The present paper should help to answer these questions.

1. Requirements for a Modern Automation System

Automation systems are automation means that have been assembled for a specific use purpose. They comprise the acquisition, transmission, processing, and utilization of information, as well as communication between man and machine. Their design must make a compromise with respect to the requirements from the perspective of the user, the manufacturer, and the theory of automatic controls. Practical procedures of optimum design and consequently the achievement of compromises that are favorable to all interested parties do not exist. Consequently, the development of automation systems proceeds largely intuitively. The above-mentioned groups of requirements are here taken into account. Reference (1) gives a comprehensive survey of existing requirements.

The requirements from the perspective of the user result

- from the development of technological processes and the resulting automation problems
- from the guidance of such processes (communication between man and machine)
- from the guarantee of high availability.

References (2) through (15) contain ideas on the same complex of problems, but with different approaches. The requirements from the point of view of the manufacturer are comprised of the following:

- Reduction of material expenditures
- Reduction of planning and production expenditures
- Controlling the throughput of orders.

References (8) and (16) through (20) consider both the requirements and formulations for their solution.

The theory of automatic control has already worked out a large number of solution algorithms and processes for the following areas:

- Treatment of complex technological systems by means of the theory of large systems. Here, technical and nontechnical characteristic quantities are taken into account in guiding the process;
- Adaptive control including real time identification;
- Regulation and optimum control of systems with distributed parameters;
- Modal regulation;
- Real time optimization of dynamic processes.

Solution possibilities exist for these areas, if presently available device capabilities are used. But this requires readiness on the part of the user of automation systems, adequate information concerning the boundary conditions to be observed by the system planner when he applies solutions, and considerable efforts for analysis of problems.

Up to now, theory has not been adequate to furnish practically oriented methods for determining target quantities, for target evaluation, and for the number of targets in solving automation problems (3). But this information is necessary in order to exhaust fully the device possibilities of automation systems that are oriented towards microcomputers.

2. Actually Implemented Automation Systems With the Microcomputer

2.1 Survey

Actually implemented automation systems can be divided, among other ways, according to the type of supply energy, the component basis for information processing, the structure of data transmission concepts that are used, and according to their use purpose. Below we shall restrict ourselves to systems with electronic information processing, and with application of the principle of digital computation. Furthermore, we shall restrict ourselves to systems which are predominantly used for acquiring and regulating measured data, but which serve only to a lesser extent for controls of predominantly process-oriented procedures.

A distinction of categories of automation systems according to their structure must take into account that at least three aspects must be considered when categorizing automation functions:

the functional aspect
the aspect of organizing functions among devices
the spatial aspect.

Accordingly, roughly two classes of automation systems with electronic devices can be distinguished (30):

1. Automation systems, whose structure is determined by linkage programs between the units (Figure 1).

   The basic characteristics of such systems are essentially determined by the device systems utilized and by their constructive elements. A fixed or variable (programmable), limited function is here assigned to each device. The total function of the system consequently and consequently the solution applied by the user, for information processing and for communication between man and machine, is fixed in the planning process.

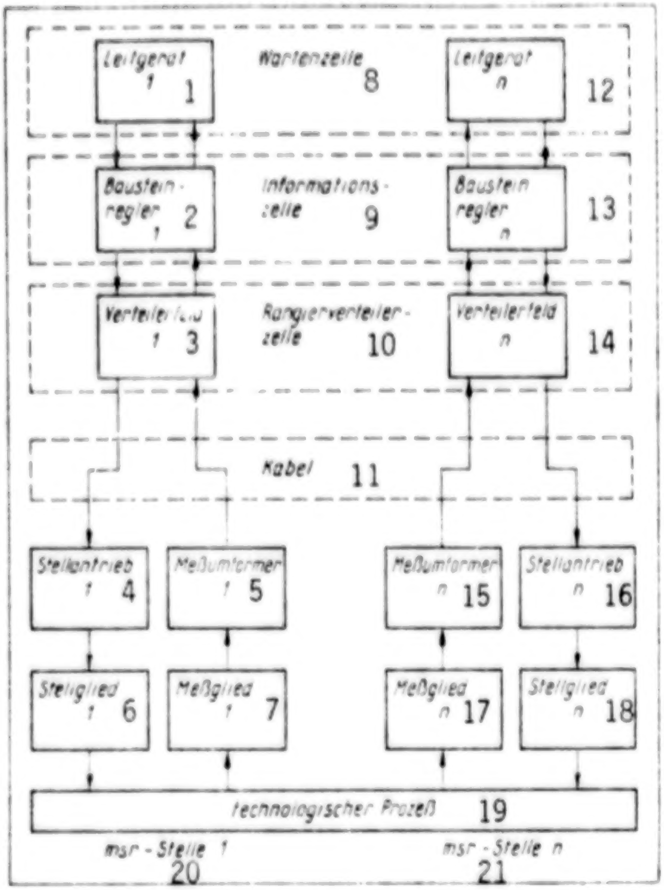


Figure 1: Structural Principle of Conventional Automation Systems (Without Process Computer)

Key:

1. Control unit 1
2. Component regulator 1
3. Distributor field 1
4. Positioning drive 1
5. Measurement converter 1
6. Positioning element 1
7. Measurement element 1
8. Service cell
9. Information cell
10. Shunting distributor cell
11. Table
12. Control unit n
13. Component regulator n
14. Distributor field n
15. Measurement converter n
16. Positioning drive n
17. Measurement element n
18. Positioning element n
19. Technological process
20. msr (measurement control regulation)- position 1
21. msr - position n

Large automation firms offer a complete spectrum of mutually coordinated elements for the system solutions. But the manufacturer of technological systems can and does assemble elements in dependence on the particular contract.

2. Automation systems, whose structure is already essentially fixed in the development stage of the automation system, and whose total function is fixed by the assemblage of elements with a complex function, with standardized solutions of information transmission (bus-systems) (below called distributed automation systems).

   Complex function elements are created for the processing and transmission of information, and for communication between man and machine. New effective principles are here used throughout:

   the principle of digital computation with information processing,

   serial digital information transmission with bus systems,

   new, qualitatively higher solutions for communication between man and machine (display screens, keyboards, light pencils, joy sticks, computer support).

   This logically extends the idea of data processing, which was introduced with the process computer.

The generation change of components extends across class 1, and influences its device solutions. On the other hand, class 2 has become possible only because of this generation change (2), (16), (18), (22), and (29).

There is a great multiplicity of solutions for 1. These solutions are determined by the device systems that are offered. Within one system, devices of different generations can be connected together. References (21) and (22) provide surveys on solutions using microcomputers. These are supplemented by new device announcements during the 1978/79 period, e.g. references (23) through (27), (46), (47), and (49).

Section 2.2 will deal with examples of actually implemented automation solutions with microcomputers and solution designs from the GDR and other CEMA countries.

References (7), (38), (40), (41), (43), (44), (51), (53), (55) through (58), and (66) through (71) are concerned with general and special questions of applying mini- and microcomputers to real time problems, under the perspectives of

structure
device technology
software
reliability.

The efforts of Soviet scientists is here especially noteworthy, to solve the problem of data processing as a whole and in principle.

The following points of special interest are here noteworthy:

Structural organization of processing, so that programming resembles that for analog computers (structural programming) and so that an engineering problem solution is thereby guaranteed (28) and (65).

A smooth and status-dependent function allocation to the elements of a multiprocessor system (67).
In this way, interlinked computer systems can be constructed which are resistant to breakdowns, which use generally unified elements, and which comprise redundancy. For example: data acquisition system B 5.

General solution of the data conversion problem (acquisition of measured values, primary processing, compaction, and distribution) (69).

Parallel processing in single computer and multicomputer systems to accelerate real time data processing and to master competitive problems, including the efficient utilization of distributed storage (40), (41), (65), and (67).

Utilization of analog components in hybrid computer complexes to accelerate processing procedures, especially in the control of complex systems with a large amount of simulation to determine the control quantities (70).

Self-diagnosis and regeneration of the automation system (68).

Between 1975 and 1977, complete system solutions were for the first time presented to the public for the automation systems of class 2. These are in part already being used industrially.

The essential characteristics of distributed automation systems, following these actually implemented solutions, will be described in Section 2.2. Comparisons and evaluations of distributed automation systems are furthermore contained in (9), (22), and (31) through (35).

2.2 Examples of Actually Implemented Automation Solutions with Microcomputers and Solution Designs

The efforts towards applying microcomputer technology to the automation technology of the GDR were significantly supported by central decisions to promote microelectronics. These efforts have led to a series of positive results. On the basis of these results, microcomputers can be widely introduced into industrial automation. Using examples, we shall below give a cross section of the status that has been achieved. Solutions of automation technology in the GDR will be primarily cited, but, using the examples of other socialist countries, excerpts will also be given of their automation technology.

1. Module basis in the GDR

a) Modular microcomputer system K 1510 of the VEB Combine Robotron (72).

This system uses the microprocessor U 808 of the VEB Radio Works Erfurt as the function-specifying core in the central processing unit. It is suitable for constructing complete microcomputer systems. The assortment of modules comprises more than 30 subassemblies and includes digital input and output modules.

b) Analog input/output modules

For these groups of modules there exist various supplements of the module assortment of the MRS K 1510. Examples are described in (24) and (75). In principle, the structure of the analog I/O modules is treated in (74).

c) Modular microcomputer system MPS 4944 of the Academy of Sciences (ZfK (Central Institute for Nuclear Research) Rossendorf) (75).

This system consists of three different CPU card types, based on the integrated circuits U 808 D, INTEL 8008, INTEL 8080, or ZILOG Z 80, of storage cards including the DMA edition, standard interface cards (Sif 1000, SI 1.2, SI 2.2, V24, ESER (uniform electronic data processing system), CAMAC and of process coupling cards for analog and digital signals. The MPS 4944 is intended to be used for research purposes.

d) Microcomputer system K 1520 of the VEB Combine Rototron (73).

The central computing unit is equipped with a microprocessor in n-MOS channel technology. Other functional units are the operative memory (4 KB), the operative read-only memory (8 KB), the read-only memory (16 KB PROM), bus extension, connection control for peripheral units (Sif 1000).

Furthermore, connection controls are provided for a display screen and a keyboard, as well as connection controls for a film memory, a V24-interface, and for a serial and parallel interface. An operating unit (with connection control) and a PROM programming device are part of the device assortment.

2. Automation equipment

a) Digital multiplex control of the VEB GRW Teltow (27)

This involves a special four-channel regulator based on the U 808 D microprocessor, which is used for temperature regulation with synthetic fiber production.

b) Multichannel microprocessor regulator of Ilmenau Technical College (24)

This regulator is constructed on the basis of the MRS K 1510 and is designed for universal application in stand-alone operation. Its functional capability has been demonstrated with application examples.

c) Microcomputer automation system SAM 80 of MMG Automatika Muevek (Hungarian VR) (23).

This involves a modular system based on the INTEL 8080 microprocessor. It can implement a representative cross section of automation functions (analog information processing, logical control, sequence control, calculations). It is suitable both for use in stand-alone operation as well as in linked operation (two-processor system). The SAM 80 comprises 28 modules, which are connected to the system bus. These modules are composed as follows:

Single card processor

Memory cards of different capacity and type (five modules). The following are used: static RAM (n-MOS or CMOS), PROM, and EPROM.
Maximum storage range (directly addressable): 65 K bytes

Time and interrupt programming, DMA (three modules)

Connection controls for magnetic tape cassettes, film memory, printer, display screen unit, service panel, as well as for dual processor (five modules)

EPROM programming unit

Bus extension

Analog input (three modules)

Analog output

DC-isolated binary inputs and outputs (optocoupler basis) (two modules)

Parallel input/output interface

BCD-coded inputs and outputs (two modules)

Keyboard connection

Universal digital input/output modules (two modules)

d) Remote processing terminal of VIDEOTON (Hungarian VR) (46)

This terminal is a modular universal automation device, which is suitable both for use in stand-alone operation as well as for use as a subordinate data acquisition and processing unit in combination with the R 10 minicomputer, in hierarchical real-time processing structures. The central processing unit contains an INTEL 8080 A microprocessor, 3/0.5 K byte PROM, and 0.5/0.25 K byte RAM. A maximum of 32 K bytes is provided as storage capacity, and this is formed by a maximum of three storage cards.

A maximum of two 16/1 K byte PROM's or a maximum of three 4/0.25 K byte RAM cards can be used (alone or mixed).

The remote processing terminal is connected with the technological process through the measurement and positioning devices, over a maximum of 256 channels, depending on the complexity of the processing tasks, because of its limited storage capacity. The process interface is formed by the process peripheral equipment of the minicomputer R 10. The usual natural and unit signals can be connected. The connection between the remote processing terminal and the R 10 minicomputer is established through a slow serial data path with 9.6 K baud transmission rate (a simple telephone line can be used). A V24 interface is here implemented.

Depending on the type of application, various data processing peripheral units are connected:

When it is used as a subordinate preprocessing unit of the minicomputer: a cassette magnetic tape unit for local data protection and filing as well as for local program loading, a printer for local print-out of data

With autonomous use: a control panel, an alphanumeric display screen unit, a cassette magnetic tape unit, a printer.

The developer specifies that the remote processing terminal can also contain microprocessors to control data transmission, for the control panel, or to operate the process peripheral equipment.

Protection of availability is guaranteed by the possibility of redundant data transmission, by on-line test programs, which run on the remote process terminal, by a redundant structure of components, and by using CMOS memories for a portion of the RAM.

The user programming system is based on a set of microprograms. It allows execution of the following tasks of the remote processing terminal:

Input of measured quantities (analog, digital, frequency)
Primary processing of measured values
Calculation of regulation and control algorithms
Output of control quantities
Generation of operating records
Self-monitoring.

The user programs can be written specific to the channel and can be modified from the control panel (inasmuch as they are stored in the RAM region of the memory).

Three program packages are offered for program development:

Cross assembler with variable instruction set (containing the instruction set of the INTEL 8080)

Higher programming language PL/M 80
This is not compatible with PL/M of INTEL. The M with PL/M 80 designates macroprogramming (not microprogramming). PL/M 80 is machine-independent. Versions are translated for the minicomputer R 10, VT 1005, and the microcomputer INTEL 8080.

INTEL 8080 simulator (developed for interactive operation through the alphanumeric display).

These program packages run under the interactive operating system IDOS on the minicomputer R 10. The finished, tested programs are written into the REPROM through a special unit, which is operated through the R 10 computer.

3. Application examples in the GDR

a) Microcomputer in stand-alone operation

Control of a distillation column (VEB GRW Teltow, 1978) (76)

Here the coupling of the microcomputer system K 1510 with conventionally instrumented control circuits was demonstrated. This application was shown in the Leipzig Spring Fair 1978.

Automatic measurement station for the continuous check of surface waters (VEB GRW Teltow, 1979) (26) (see Page 598)

Control of the injection molding process (Technical College Karl-Marx-Stadt, 1978) (77)

This example treats a relatively demanding control problem, which is decomposed into partial controls, which are successively implemented. This method pursues a pragmatic mode of procedure. For the partial controls of the process steps of form filling, a solution formula has been worked out which is intended for processing on the MRS K 1510.

Digital water level regulation for an 815 t/h steam generator (Technical College Karl-Marx-Stadt, 1977/78) (78)

Starting from the existing solution in the Hagenwerder III Power Plant, the design of a digital regulator, based on the MRS K 1510 is treated. This regulator controls the water level with load-dependent parameters, without a connection to the central process computer R 4000. The programming system that been developed was tried out under laboratory conditions.

Parameter-controlled DDC regulator based on a microcomputer (Central Institute for Cybernetics and Information Processes of the AdW (Academy of Sciences)) (79)

This involves the conversion of algorithmic studies to adaptive regulators. It specializes in processes which have parameters that depend on the operating point, such as occur e.g. when starting up or shutting down power plant processes. The regulator was constructed on the basis of the INTEL 8080, and it was tried out under laboratory conditions.

b) Several coupled microcomputers

Microcomputer network for the Boxberg Power Plant (Institute for Energetics Leipzig, 1977/78) (28)

This application case comprises a connected system of several microcomputers. Each of these is assigned to a power plant block and outputs the real and reactive power as well as the idling amounts and other technical quantities, with a central computer in the dispatch control room of the power plant. An overall view of the power plant is maintained there. By means of a band of characteristic curves, control directives are calculated for each generator. After release by the dispatcher, these are transferred to the block computer.

The core of the MR (microcomputer) network is the microcomputers based on the INTEL 8008 integrated circuit. The data connection is implemented through the existing telephone lines bit-serially with asynchronous data transmission (1200 baud).

Special attention was paid to reducing the noise in data transmission.

Process control technology with microcomputers - PLM 4000 (VEB GRW Teltow, 1979) (25)

In the further development of the Ursamat K 4000 system, microcomputers were integrated into the automation system, in order to achieve an extension of the spectrum of tasks, especially the creation of a powerful control level. It is anticipated that the system will be used in conventionally instrumented automation systems, to create a process-intensive control level or to implement complicated multiple controls. The microcomputers here implement the following functions:

Acquisition of the measurements of analog quantities

Processing of measured data

Outputting information through display screen, serial printer, and paper tape punch

Digital multiple control

Direct control to design values of conventionally instrumented control circuits

Remote parameter adjustment of conventional modules.

Figure 2 shows the structure of the process control technology. Microcomputer 1 is used for information processing, to support communication between man and machine. It is therefore equipped with operating, display, and recording units having new operating principles (alphanumeric display screen, keyboard, printer, magnetic cassette memory).

The microcomputers 2 are intended for the input and output of analog and binary signals and for their processing through algorithms of the automatic control. For this reason, they can be connected to the measurement and control technology of current or recent operating principles, as well as to the control units of conventionally instrumented control circuits or to permanently wired controls.

The channels of the conventional systems are here treated like MSR (Measurement Control Regulation) locations. The coupling possibilities are explained in more detail in (25).

Signals derived from process controls (e.g. signals formed by the protective system) intervene directly at the control level through a supplementary logic circuit, without additional operator action being necessary.

If a computer fails, a message is transmitted by the supplementary logic circuit to the conventional system. For example, with analog control circuits, this causes the control unit to change over to design values which are continuously calculated internally.

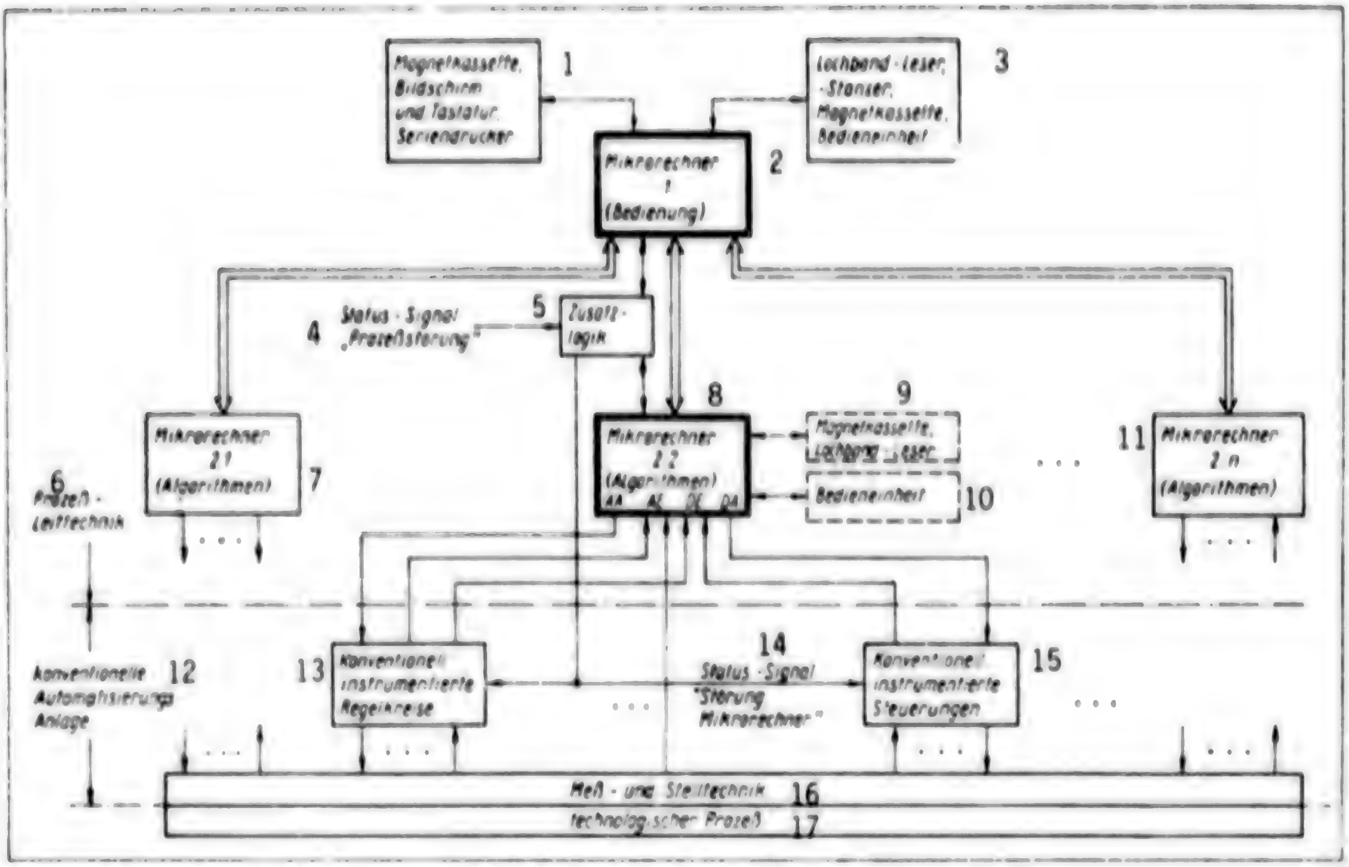

Magnetkassette, Bildschirm und Tastatur, Seriendrucker
1
Lochband-Leser, -Stanzer, Magnetkassette, Bedieneinheit
3
Mikrorechner 1 (Bedienung)
2
Status-Signal „Prozeßstörung"
4
5
Zusatzlogik
8
9
Mikrorechner 2.1 (Algorithmen)
7
6
Prozeß-Leittechnik
Mikrorechner 2.2 (Algorithmen)
AA AE DE DA
Magnetkassette, Lochband-Leser
Bedieneinheit
10
...
11
Mikrorechner 2.n (Algorithmen)
...
...
konventionelle Automatisierungs-Anlage
12
13
Konventionell instrumentierte Regelkreise
14
Status-Signal "Störung Mikrorechner"
Konventionell instrumentierte Steuerungen
15
...
...
...
...
...
Meß- und Stelltechnik
16
technologischer Prozeß
17

Figure 2: Structure of the Process Control Technique PLM 4000

——— Operating equipment, - - - Equipment for start-up and service, AE analog input, AA Analog output, DE digital input, DA digital output

Key:

1. Magnetic cassette, display screen, and keyboard, serial printer
2. Microcomputer 1 (Operation)
3. Paper tape reader, puncher, magnetic cassette, operating unit
4. Status-signal "process disturbance"
5. Supplementary logic
6. Process control technique
7. Microcomputer 2.1 (algorithms)
8. Microcomputer 2.2 (algorithms) AA AE DE DA
9. Magnetic cassette, paper tape reader
10. Operating unit
11. Microcomputer 2.n (algorithms)
12. Conventional automation system
13. Conventional instrumented control loops
14. Status signal "disturbance microcomputer"
15. Conventional instrumented controls
16. Measurement and positioning technique
17. Technological process

The microcomputer system K 1510 and the solutions of Ilmenau Technical College (24) for the process coupling form the device basis for the PLM 4000.

The computers are coupled among one another either through a direct coupling of the I/O gates or by using the connection control units ADA, ASI, or ASV of the K 1510 (depending on the distances that are required between the computers).

The microcomputers are set up spatially concentrated in the control room. The program sequence in the microcomputers is organized through framework programs for the operating modes "on-line operation" and "off-line operation". The software has modular construction and permits flexible adaptation to special problems. The following standardized program modules are used:

Data exchange between computers (with self-monitoring)
Communication programs
Clock program
Acquisition of measured values for analog and digital signals
Primary processing of measured data
Processing of measured data
Output of measured data for analog and digital signals
Special modules.

The sofware is adapted to the particular application case by generating lists.

The process control technology PLM 4000 was presented at the Leipzig Spring Fair of 1979, using as an example the guidance of a power plant block to its design value, based on component loads during start-up and slow-down. It is intended to be used, among other purposes, as supplementary equipment for conventionally instrumented power plant automation systems.

Control system CNC 600 (VEB Numerik "Karl Marx", Karl-Marx-Stadt, 1979) (80)

CNC 600 is a multicomputer system for the numerical control of tool machines. It is based on the K 1520 microcomputer system and on the U 880 microprocessor integrated circuits. The functions of the numerical control are distributed among individual microcomputers (static task distribution). These microcomputers work autonomously and simultaneously. They are sometimes connected for the purpose of data exchange.

The computers can be arranged in decentralized fashion. Their associated program technology is divided in accord with their performance limits into

Programs of the manufacturer of the CNC (control program system, evaluation programs, service programs)

Programs of the user of the CNC (workpiece programs, adaptation programs)

The control system CNC 600 was distinguished by a gold medal at the Leipzig Spring Fair of 1979.

Automation of electrical power generating systems with microcomputers (VEB KEAB Berlin, 1978) (73)

A computer hierarchy is constructed on the basis of the K 1510 microcomputer system. It consists of a control computer and several unit computers (one microcomputer per diesel generator unit).

The unit computers here implement the following functions:

Starting up and stopping the unit
Synchronization
Controlling and regulating the frequency
Monitoring the operating mode
Determining the real power.

The control computer has the following tasks:

Selecting the units which are to be connected or disconnected
Interrogating the load factor
Control with incomplete load
Deviation from requirements in case of overload
Representing the real power.

This solution was exhibited in the Leipzig Spring Fair of 1978.

Automation of a rolling mill process with microcomputers (VEB KEAB Berlin, 1979) (81)

This involves a multicomputer system for data acquisition, control of component processes of a rolling mill, and their coordination. The microcomputer system K 1520 was used as a basis. The computers are connected together in an hierarchical structure, without being spatially decentralized.

This application was exhibited at the Leipzig Spring Fair in 1979.

2.3 Essential Characteristics of Distributed Systems

2.3.1 System Design

At this time, two system designs can be roughly distinguished, according to the manner in which the complex elements are linked (1), (31), and (35):

a) Utilization of a bus system in the control area (Figure 3)

The information processing equipment (analog, hybrid, or digital functional units) are spatially centralized and are set up in the control room or the auxiliary control room.

In principle, it is possible to operate the system through these functional units. By means of a bus system, they are connected to a communication system with display and process intervention capabilities (e.g. keyboard).

The communication system works with computer support (process computer or microcomputer).

This system design represents a compromise between a conventional and a totally distributed system (37), (42), and (45).

b) Utilization of one or more bus systems in the control and process area.
Two subdesigns can here be distinguished:

b1) Connection of equipment with different functions (information processing and acquisition, process computer, communication between man and machine) to the same bus branch (Figure 4).

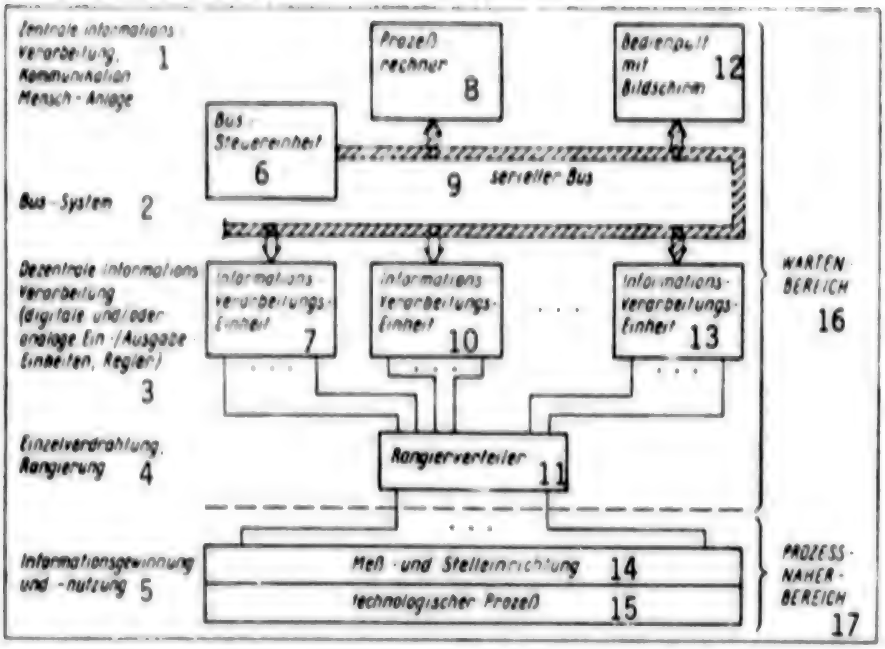
This bus branch is designed as a line or ring bus with electrical or light-type transmission. It traverses the entire system (48), (49), (50), and (51).

b2) Connection of equipment of the same or similar function to specialized bus branches (Figure 5).

In the control area and in the process-near area, different bus systems can thus be used (52).

2.3.2 Transmission of Information

With most of the actually implemented systems, digital serial information transmission, based on electrical lines (long-distance lines with few strands or HF coaxial cables) is used between the microcomputer-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Prozeß rechner 8
Bedienpult mit Bildschirm 12
Bus-Steuereinheit 6
9 serieller Bus
Bus-System 2
Dezentrale Informations-Verarbeitung (digitale und/oder analoge Ein-/Ausgabe-Einheiten, Regler) 3
Informations-verarbeitungs-Einheit 7
Informations-verarbeitungs-Einheit 10
Informations-verarbeitungs-Einheit 13
WARTEN-BEREICH 16
Einzelverdrahtung, Rangierung 4
Rangierverteiler 11
Informationsgewinnung und -nutzung 5
Meß- und Stelleinrichtung 14
technologischer Prozeß 15
PROZESS-NAHER-BEREICH 17

Figure 3: System Design (a)
Utilization of a Bus System in the Control Area

Key:

1. Central information processing, man-machine communication
2. Bus system
3. Decentralized information processing (digital and/or analog input/output units, control)
4. Single wiring, shunting
5. Information acquisition and utilization
6. Bus control unit
7. Information processing unit
8. Process computer
9. Serial bus
10. Information processing unit
11. Shunt distributor
12. Control console with display screen
13. Information processing unit
14. Measurement and control device
15. Technological process
16. Control area
17. Process-near area

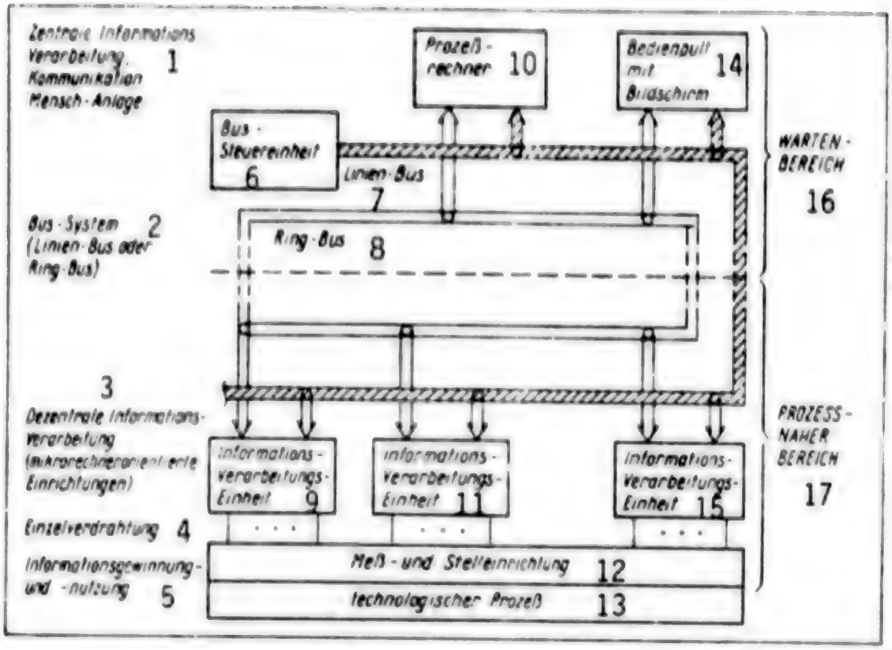
Zentrale Informations Verarbeitung, Kommunikation Mensch-Anlage 1
Prozeß-rechner 10
Bedienpult mit Bildschirm 14
Bus-Steuereinheit 6
Linien-Bus 7
WARTEN-BEREICH
16
Bus-System 2
(Linien-Bus oder Ring-Bus)
Ring-Bus 8
3
Dezentrale Informations-Verarbeitung (mikrorechnerorientierte Einrichtungen)
Informations-Verarbeitungs-Einheit 9
Informations-Verarbeitungs-Einheit 11
Informations-Verarbeitungs-Einheit 15
PROZESS-NAHER BEREICH
17
Einzelverdrahtung 4
Informationsgewinnung- und -nutzung 5
Meß- und Stelleinrichtung 12
technologischer Prozeß 13

Figure 4: System Design (b1)
Utilization of a bus system in the control and process area; connection of equipment with different functions to the same bus branch

Key:

1. Central information processing, man-machine communication
2. Bus system (line bus or ring bus)
3. Decentralized information processing (equipment oriented towards microcomputers)
4. Single wiring
5. Information acquisition and utilization
6. Bus control unit
7. Line bus
8. Ring bus
9. Information processing unit
10. Process computer
11. Information processing unit
12. Measurement and positioning device
13. Technological process
14. Operating console with display screen
15. Information processing unit
16. Control area
17. Process-near area

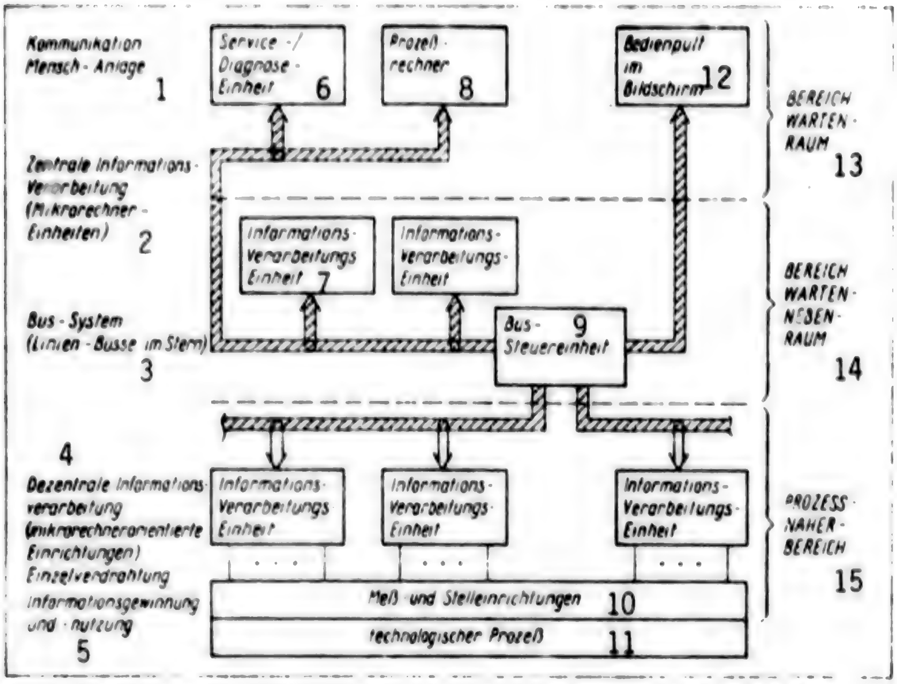
Kommunikation Mensch - Anlage
1
Service -/ Diagnose - Einheit
6
Prozeß - rechner
8
Bedienpult im Bildschirm
12
BEREICH WARTEN - RAUM
13
Zentrale Informations - Verarbeitung (Mikrorechner - Einheiten)
2
Informations - Verarbeitungs Einheit
7
Informations - Verarbeitungs - Einheit
Bus - System (Linien - Busse im Stern)
3
Bus - Steuereinheit
9
BEREICH WARTEN - NEBEN - RAUM
14
4
Dezentrale Informations - verarbeitung (mikrorechnerorientierte Einrichtungen) Einzelverdrahtung
Informations - Verarbeitungs Einheit
Informations - Verarbeitungs - Einheit
Informations - Verarbeitungs - Einheit
PROZESS - NAHER - BEREICH
15
Informationsgewinnung und - nutzung
5
Meß - und Stelleinrichtungen
10
technologischer Prozeß
11

Figure 5: System Design (b2)
Utilization of a bus system in the control and process area; connection of equipment with the same or similar functions to specialized bus branches

Key:

1. Man-machine communication
2. Central information processing (microcomputer units)
3. Bus system (line buses in a star)
4. Decentralized information processing (equipment-oriented towards microcomputers) single wiring
5. Information acquisition and utilization
6. Service-/diagnostic unit
7. Information processing unit
8. Process computer
9. Bus control unit
10. Measurement and positioning equipment
11. Technological process
12. Control console with display screen
13. Control area
14. Auxiliary control area
15. Process-near area

oriented devices (37), (42), (45), (48), (50), and (52). Depending on the application purpose, net transmission rates of 9.6 K baud to 1500 K baud are here reached. When using light pipes, a net transmission rate of 10,000 K baud is achieved.

Light-pipe transmission has therefore reached industrial maturity; however, its use is just beginning.

The transmission procedures depend on the system. Telegrams with a length of about 25 to 75 bits are transmitted. Error-detecting and error-correcting codes are used throughout.

Centralized bus control, concentrated on a unit, prevails.

A survey of existing solutions and detailed specifications are contained in (31), (34), and (35). The problem of standardizing the bus systems is treated, among other places, in (60) and (61). International efforts towards standardization have up to now not been completely successful.

The coupling between the equipment for information acquisition and the equipment for information processing is generally still effected through the traditional connection principles based on electrical unit signals. In this area, considerable changes are expected in the near future, through the development of measurement and control equipment with serial interfaces. The associated interface questions are treated in (62).

2.3.3 Processing of Information

In the distributed systems, the processing of information is divided into centralized and decentralized information processing (31) and (35).

For both groups, one part is implemented for executing the actual automation tasks and one part of auxiliary functions is implemented for organizing the information processing in the distributed system (designated below by +).

1. Central information processing (predominantly in the control area)

   Information processing for man-machine communication (with display screen-oriented controls in the operating panel). Among these belong the following:

      Allocation of information from the MSR locations to display screen contents +).

      Preparation of input signals of the operating personnel and transmission to centralized and decentralized information processing units +).

      Alarm treatment.

Control of data exchange between information processing units through the bus (generally through data path control units) +)

Monitoring the function of information processing units, forming and processing status signals (by data path control units or by the control panel) +)

Computation of complicated algorithms (process computer)

Processing of measured data, extensive control tasks (in process computers, specially programmed universal microcomputer units or in special control units).

Preparation of large quantities of data for filing (process computer, control panel)

2. Decentralized information processing (in the control and/or process area)

Acquisition and output of analog and/or binary measured quantities as well as counter pulses (by analog/hybrid or digital equipment)

Primary processing of measured data (by digital microcomputer units)

Regulation (complete) and control of a smaller scope (in analog devices and/or universal digital microcomputer devices)

Preparation, statizing, and preparation of data, which are transmitted through the bus (digital equipment, generally microcomputer-oriented) +)

Formation and preparation of status signals for self-monitoring of the decentralized information processing units
(always through the microcomputer equipment, but the proportion of hardware and software effort may be different) +)

There is a plethora of actually implemented solutions. Survey information is contained in (31), (32), and (35).

2.3.4 Communication Between Man and Machine

Ideas and solutions concerning man-machine communication have been presented in a large number of recent publications (4) through (6), (10) through (13), (31), (35), (59) and (63). Roughly two control designs can here be distinguished with the actually implemented distributed systems, (31) and (35):

1. Conversational mode traffic between man and machine occurs predominantly with conventional control instrumentation. This design is used when information processing occurs mainly in conventional, analog information processing units. The display screen-oriented control panels are used to provide survey information for the control personnel either

   with possible intervention in the process (37) and (52) or without a possible intervention in the process (54).

2. Conversational mode communication between man and machine occurs at display screen-oriented control panels. This design contains two sub-designs:

   Design of one-man work stations with three to four display screens to guide the process and for technical diagnosis. Conventional display and recording units as well as operator equipment are possible, but do not predominate (48).

   A conventional representation of information and the operation on the front panels of the information processing units are integrated into the communication system. However, the process is primarily controlled from display screen-oriented control panels, (42) and (45).

Depending on the traditions of the use area of the system, the device technology within the control room is organized variously. In power plant technology, a highly functional spatial organization is the practice corresponding to the activities of the system operator and of the operating personnel.

For communication between man and process (block control), a division is made into a main control station, an auxiliary control station, and a documentation area. For communication between man and the control station, one uses the diagnostic and service station (52).

On the other hand, in process technology, the man-process (system operator) communication and the man-automation communication (technical operating personnel, maintenance) is implemented through the same devices.

The actually implemented solutions for process control (i.e. communication between man and the automated process) are so extensive that they will not be presented in detail. Agreements appear precisely in this area.

2.3.4.1 Presentation of the Process Status with Display Screens

Quasi-graphic color display screen units are used for this purpose. As a rule, the depth of detail of the information representation can be selected arbitrarily on the display screen:

a) A survey display
b) A group display of measured data
c) A detailed display.

Both tabular assemblages of information from various (e.g. functional) perspectives as well as the inclusion of process information in a technical flow chart can be used.

A special convenience is the capability of generating a picture, tailored to the specifics of the application case or of the operator. This facilitates the following:

Designing the picture background
Selecting certain symbols from an inventory
Coding the information and
"Planting" current process information.

2.3.4.2 Operating Strategies and Means

With display screen-oriented solutions for the control panel, conversational mode operation occurs with the transmission of information being guided in a highly specific manner. Here the operator makes a specific selection of information. He obtains "conceptual support" from the communication equipment, i.e. he is himself guided through directives on the respectively chosen image format. Hierarchical transmission of information and the color are significant aids.

The linked representation of functionally associated information also supports the operator significantly. The following are used as operating means:

Alphanumeric and function-oriented keyboards (with all systems)

Virtual keyboards, i.e. representations of keys on the display screen, activation with a light pencil or cursor (51), (52), and (59).

Light pencils as operating means in PR (process computer) peripheral systems (45), (51), (52), and (59).

Joy sticks and rolling balls as controls in PR peripheral systems (51) and (52).

2.3.4.3 Alarm Treatment

As a rule, the system operator is alarmed optically through the display screen units and through special alarm devices. The following are here used:

a) Particular coding of the display screen information, e.g. color change, negative display, blinking of the appropriate line, special symbols;
   This information is offered in the various depths of detail of the information of hierarchy, and additional directives for remedies are also offered.

b) Special alarm overviews on a display screen, (37), (48) and (49).

c) Alarm indicator boards, (42) and (48), either connected through the bus or wired directly, (37).

d) Special alarm printers, (37), (45), and (48).

The further development of communication means promises further perceptible facilitations for the system personnel. The processing power of the communication systems will be expanded, and the system operator will be offered more "conceptual support". This will liberate him from direct routine work, so that he can apply himself to real process control tasks. The real time character of the information processing will here penetrate to the level of enterprise-combine management, (33), (39), (55) through (57), (60) and (65). New communication means, such as wide-area color displays based on LED elements, plasma displays (43), multivision walls, and speech input units (64), will improve the ergonomic aspects of the man-machine interface.

2.3.5 Reliability

For distributed systems, both conventional back-ups as well as redundancy measurements are used within the distributed system (8), (22), and (35).

a) Measures for increasing availability that are contained within the system

   Self-monitoring of equipment and formation of status signals (with all systems, but with different convenience), indication of errors and of repair recommendations

   Application of test codes to secure data transmission (with all systems)

Modular structure of the central equipment (microcomputer-oriented control technology) and transfer possibilities of the function to neighboring equipment with lesser convenience (with all systems)

Redundancies

Conventional control technology possible as conventional back-up (37), (42), (45), (48), (49), and (52)

Redundant data path control unit (45), (48), (50), and (52)

Redundant data path (48) and (52)

Reserve information processing unit (48) and (52)

b) Measures to be planned

Organization of the system in several levels corresponding to the functional hierarchical organization of automation tasks with the loosest possible coupling of the upper level to the respectively lower level (can be implemented in principle with all systems)

Structural measures, generally connected with the required redundancy, e.g. ring structures (50) and (51), network structures, introduction of decentralized bus control (51).

Securing adequate software reliability by adequate tests in the start-up phase

Hot redundancy for the microcomputer/process computer equipment by the same computer technology.

Systems corresponding to the design (b2), using specialized bus branches, are advantageous in the sense of reliability. For example, the central information processing equipment can here be doubled (hot redundancy, directly connected to the bus), without additional expenditures being necessary for the preparation of information (52).

On the other hand, for systems corresponding to the system design (b1), all the necessary process signals must be conducted to the reserve unit with special cables (e.g. standard cables with "non-interruptible control system" in the TDC 2000 (48)).

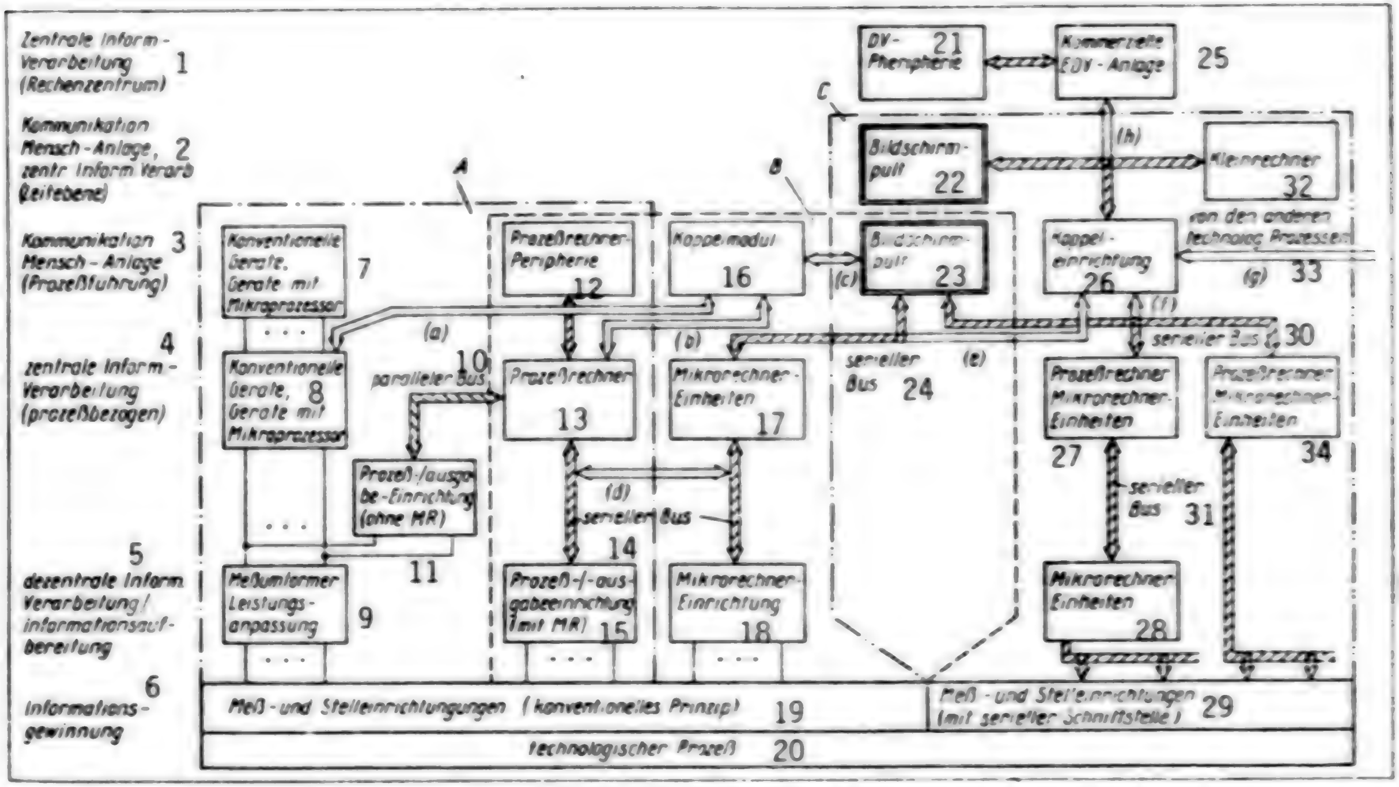
Zentrale Inform.-Verarbeitung (Rechenzentrum) 1
Kommunikation Mensch-Anlage, zentr. Inform.Verarb. (Leitebene) 2
Kommunikation Mensch-Anlage (Prozeßführung) 3
zentrale Inform.-Verarbeitung (prozeßbezogen) 4
dezentrale Inform.-Verarbeitung/ Informationsaufbereitung 5
Informationsgewinnung 6
DV-Pheripherie 21
Kommerzielle EDV-Anlage 25
C
A
B
Bildschirmpult 22
(h)
Kleinrechner 32
Konventionelle Geräte, Geräte mit Mikroprozessor 7
Prozeßrechner-Peripherie 12
Koppelmodul 16
Bildschirmpult 23
Koppeleinrichtung 26
von den anderen technolog. Prozessen
(g) 33
(c)
(a)
(b)
(f)
seriellerBus 30
Konventionelle Geräte, Geräte mit Mikroprozessor 8
10 paralleler Bus
Prozeßrechner 13
Mikrorechner-Einheiten 17
serieller Bus 24
(e)
Prozeßrechner Mikrorechner-Einheiten 27
Prozeßrechner Mikrorechner-Einheiten 34
Prozeß-/ausgabe-Einrichtung (ohne MR) 11
(d)
serieller Bus 14
serieller Bus 31
Meßumformer Leistungsanpassung 9
Prozeß-/-ausgabeeinrichtung (mit MR) 15
Mikrorechner-Einrichtung 18
Mikrorechner Einheiten 28
Meß- und Stelleinrichtungungen (konventionelles Prinzip) 19
Meß- und Stelleinrichtungen (mit serieller Schnittstelle) 29
technologischer Prozeß 20

Figure 6

Figure 6: Maximum Configuration of an Automation System (Greatly Simplified)

——— Single-wire cabling
//////// Necessary bus connections
═══ Possible bus connections

The exact structure of the information coupling of the elements (e.g. bus structure) has not been shown for the sake of clarity

A Conventional automation system with process computer, Class 1 (to guide a technological process)
B Automation system with distributed information processing, Class 2 (to guide a technological process)
C Totally distributed automation system (for process and operating guidance)

Key:

1. Central information processing (computer center)
2. Man-machine communication, central information processing (control level)
3. Man-machine communication (process guidance)
4. Central information processing (specific to the process)
5. Decentralized information process/information preparation
6. Acquisition of information
7. Conventional devices, devices with microprocessor
8. Conventional devices, devices with microprocessor
9. Measurement transformer, power matching

Figure 6 Key Continued

10. Parallel bus
11. Process/output equipment (without MR)
12. Peripheral equipment for process computer
13. Process computer
14. Serial bus
15. Process/output equipment (with MR)
16. Coupling module
17. Microcomputer units
18. Microcomputer equipment
19. Measurement and positioning equipment (conventional principle)
20. Technological process
21. Data processing peripheral equipment
22. Console with display screen
23. Console with display screen
24. Serial bus
25. Commercial EDP system
26. Coupling equipment
27. Process computer, microcomputer units
28. Microcomputer units
29. Measurement and control devices (with serial interface)
30. Serial bus
31. Serial bus
32. Minicomputer
33. From other technological processes
34. Process computer, microcomputer units

3. Conclusions for Designing Automation Systems

3.1 Maximum Configuration

The actually implemented distributed systems, which were treated in Section 2, are tailored to certain preferred use area (e.g. to process technology and to power plants) or to systems of a definite size (e.g. 1000 MSR locations). For this limited use spectrum, complete system solutions can thereby be planned. In implementing large-scale systems, and to control the change of generations of automation technology (especially from the perspective of the operator), mixtures of systems from different manufacturers and generations are required.

From this perspective, Figure 6 shows the necessary maximum configuration of an automation system (greatly simplified). It can be seen that both the components for implementing conventional systems (with and without process computer), distributed systems (with and without serial interface of the measurement and control technology), as well as mixed systems can be projected therefrom as an extreme variant with large-scale installations.

This maximum configuration is at this time achieved by no actually implemented system. It can serve as a terminus for the development and advanced development of systems. The possible bus connections specified in Figure 6 have the following meanings:

(a) + (c) Connection of individual devices with the microcomputer through the bus, for communication with the display screen console. This implements a coupling of systems of Class 1 with systems of Class 2.

(b) + (c) Connection of process computers (PR) to the display screen console. The PR with a data processing and process peripheral unit is included in the distributed automation system (in coordination by the display screen console), and man-process communication is carried on from the display screen console.

(d) Direct connection between the information processing units with the microprocessor and the PR system. The process computer is coordinated with the information processing units. It is thus subordinated within the regime by means of which the system bus is operated.

(e)(f)(g) Connection of an automation system for a limited technological process to a supervening control level.

(h) Coupling of the control level with an operational computer center. This creates the presupposition for "real time processing in the large" (quasi-real time processing on the enterprise/combine level).

3.2 Problems to be Solved

From the multiplicity of problems, two groups will be selected, which currently intensely occupy the developers and manufacturers of automation systems:

Controlling the interfaces with large-scale systems

Limits and obstacles for the progress of decentralization.

3.2.1 Controlling the Interfaces

Coupling and interface problems exist regarding the juncture of devices, equipment, or component systems from different suppliers and different generations, the adaptive processing of different classes of problems, which is handled by different specialists, and with respect to the implementation of large, extremely interlinked combination systems on a large scale. Several explanations and ideas on these points will be presented below:

Coupling of Solutions from Different Manufacturers and Generations

Figure 6 clarifies the problem. It should be especially noted that new and advanced development must guarantee adaptability not only within the new device and system generation, but the sum of the new developments must replace the devices and the equipment that is currently in production. During a transition period, the systems of devices will have to be intermixed to a limited extent. The device and system manufacturers generally proceed in such a fashion that the control technology and/or the devices of the central information processing are first replaced by microcomputer-oriented solutions (display screen consoles, decentralized information processing units). These solutions can be connected either with conventional measurement and control equipment or with conventional regulators. Afterwards, extensions are made with respect to the process measurement and control technology, with serial interfaces and with the coupling of component systems among one another, and with the supervening control levels. The following factors facilitate solution of the problem:

Development of intelligent, programmable interfaces (coupling module/devices corresponding to Figure 6), which are used both as a delivery limit and for decoupling the component systems (with respect to time and data organization).

Standardization of data transmission

Creation of solutions for component systems (basic systems) with closed functions (e.g. information processing and man-machine communication) for about 1000 MSR locations

Adaptable processing of different classes of problems.

Specialized systems are limited to restriced classes of problems (predominantly the acquisition M and regulation R of measured data, a few control functions with systems for process technology, predominantly controls S with systems, e.g. for rolling mill and cement plant automation). Such systems are inadequate for complex automation problems, e.g. power plant automation.

Figure 7 shows a typical structure of a distributed automation system. Starting from this structure, essentially three variants can be distinguished for distributing the tasks R and S (Table) (36).

In favor of variants 1 and 2 speak the clear, easily planned, specialized design of the subsystems; variant 3 is favored by the trend towards decentralization (on-site automation of closed technological function complexes). The decision will be made on the basis of an analysis of the information flow between R and S as well as between and on the data paths.

Table: Variants of the Distribution of the Problems of Acquiring, Regulating (R), and Controlling (S) Measured Values in Distributed Automation Systems

F_{wi}
F_{vij}

Function	Variant 1 coupled specialized R- and S-subsystems	Variant 2 coupled subsystems with specialized R- and S-equipment	Variant 3 coupled subsystems with mixed equipment
F_{w1}	S	S/R	S/R
$F_{v1.1}$	S	S	S/R
$F_{v1.m}$	S	R	S/R
F_{w2}	R	S/R	S/R
$F_{v2.1}$	R	S	S/R
$F_{v2.n}$	R	R	S/R

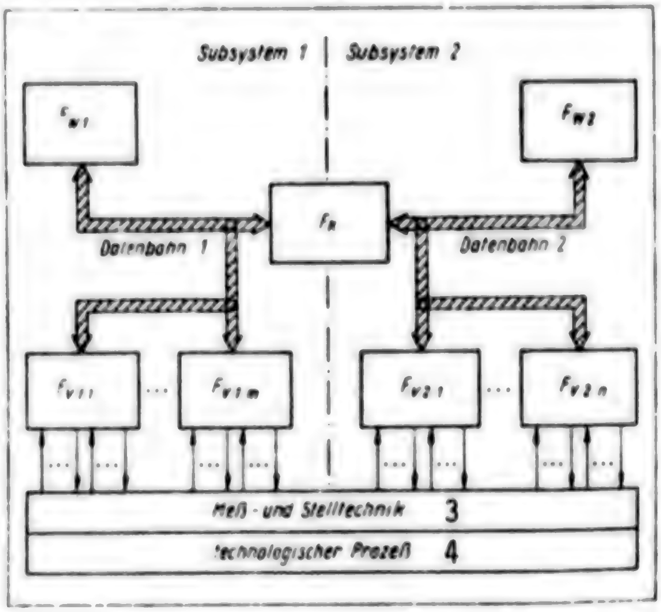

Figure 7: Structure of a Distributed Automation System With Two Coupled Subsystems

F_W Operation and display, recording (service function);
F_K Coupling, data exchange; F_V Information processing

Key:

1. Data path 1	3. Measurement and positioning technique
2. Data path 2	4. Technological process

Besides the adaptability of the information processing, a common operating regimen for R and S is required, if communication is to take place over a uniform control console. Likewise, a uniform software system frame is required (36).

Implementation of large, highly interlinked systems

Starting from the supposition that the above problems have been solved, the following additional tasks must also be solved:

Controlling the organization of an interlinked system by a clear subdivision into subsystems, which are decoupled with respect to time organization. In principle, various solution variants of distributed automation systems can be used to implement the subsystems.

Avoiding competitive situations in interlinked systems by a clear organizational specification of the collaboration of the subsystems.

Rapid data transmission; this requirement will be fulfilled by using light pipes.

3.2.2 Limits and Obstacles for the Progress of Decentralization

The following significant problems prevent rapid implementation of local decentralization in the industrial use of distributed automation systems:

Conversion of equipment in measurement and control technology. Because the devices exhibit a multiplicity of variants, it will take a considerable amount of time to furnish devices with serial interfaces for connection to bus systems, to be used throughout the automation systems (implementation of totally distributed automation systems).

Time and organization problems when using on-site information processing units for data collection and distribution.
The structure of highly subdivided hierarchical process data processing systems carries with it the danger of slowing down the processing of the information. Relative to one MSR location, the processing effort for organizing data traffic and data treatment will increase.

A sensible compromise between single-channel solutions with bus connection and multi-channel solutions (in the sense of "mass process data processing") represents a way out of this impasse. Such a compromise may look as follows: The predominant portion of automation tasks require less availability (more than 80 percent of the implemented functions are used for measurement and display). For such tasks, multi-channel data collection and distribution devices can be used in their process technology. Such devices will implement the primary processing and regulation (about 10 percent) of the measured data. On the other hand, complicated regulation processes, controls, and MSR locations require high reliability. For these functions, single-channel devices, or devices with a few channels can be used.

This problem can be solved in a more thoroughgoing fashion if one introduces parallel processing and a smooth, status-dependent allocation of functions to the elements of the multicomputer system (40), (41), (65), and (67).

Creation of large containers for the application classes, which occur with direct on-site use of the intelligent microcomputer-oriented devices.

The intrinsically reliable design of the coupling of "on-site processing unit with measurement unit/control device" and of the bus system for coupling the on-site processing unit with the centralized information processing units, as well as the communication device must here be simultaneously guaranteed.

The cluster of problems mentioned here is the reason that decentralization, which would increase efficiency (e.g. a saving of cables), and which is hoped for by the manufacturers of the distributed systems, cannot at this time be fully utilized.

Adaptation of the power supply system to the device hierarchy in distributed systems

The following distinctions can here be made:

Supplying power for devices to acquire and process information

A favorable compromise between a central power supply and a completely decentralized power supply must be found in the sense of the overall system. This compromise can consist in implementing only coarse power supply (with fail-safe protection) and in furnishing specialized power needs in decentralized fashion. When reaching such a compromise, the manner in which the supply energy is transmitted (together with the bus system or through a separate cable network) is an essential influential quantity.

Power supply for the control equipment

Especially with control equipment for electrical quantities (e.g. drives with medium and large power), centralized switching system structures require considerable material expenditure for the transmission of supply energy from the switching system to the on-site control device. As an alternative, one can propose a "power bus" adapted to the "information bus system". But this requires considerable development efforts for the drive solutions. These lead to a decentralized, distributed switching system. The savings in cables that are made possible thereby exceed the savings possibilities for introducing the "information bus systems".

4. Consequences for Automation System Construction in the GDR

The spectrum of needs that must be satisfied by automation system construction in the GDR extends from process technology through power plants, rolling mills, cement works, up to tool machine control.

For this reason, it is necessary, for a large part of this spectrum, to create a highly modular system with essentially unified hardware modules. This system will have supplementary modules that are tailored for various application classes. It will also feature user-specific configurations and software development. In this way, it will become applicable to specific applications.

The module assortment Ursatron 5000 of the combine VEB KEAW Berlin is intended for the new device generation Ursamat 5000. It fulfills the above purpose and is based on the K 1520 microcomputer of the VEB Combine Robotron. This module assortment uses multi-channel decentralized devices (basis units, Ursadat 5000, Ursalog 5000), and communication devices with display screen, as well as a bus system (compare B in Figure 6). In parallel thereto, microprocess-oriented individual units with interfaces for bus connection are also being created (Ursamar 5000). Thus, depending on the development status of the equipment and devices, various generations with different application orientations (small or large systems) can be deployed mixed in specific automation systems.

Special attention is paid to standardizing the interfaces for uniform application in the process computer technology of the new generation (family K 1600 of the VEB Combine Rototron) and in automation systems with distributed information processing (microcomputer basis; Ursamat K 5000).

Suitable special solutions will be created for individual technological lines of the demand spectrum, e.g. the CNC 600 system for tool machine controls.

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GERMAN DEMOCRATIC REPUBLIC

PROGRAMMING OF COMPUTERIZED NUMERICALLY CONTROLLED MACHINE TOOLS

East Berlin MESSEN-STEUERN-REGELN in German Vol 22 No 10, Oct 79
pp 575-579

/Report by Dr. W. Gehlsdorf, engineer; H. Kessner, K. Schroeter, and M. Stoll, engineers, Research Center for Machine Tool Building, VEB Fritz Heckert Machine Tool Combine, Karl-Marx-Stadt: "Machine Tools With Computerized Numerical Control and Their Programming"7

/Text7 0. Introduction

The development of numerically controlled tool machines has recently received a new impetus through microelectronics. Permanently wired NC's (numberical control) have been generally replaced by CNC's (computer numerical control). Mechanical subassemblies of the tool machines have partly been replaced by electronic devices (Figure 1).

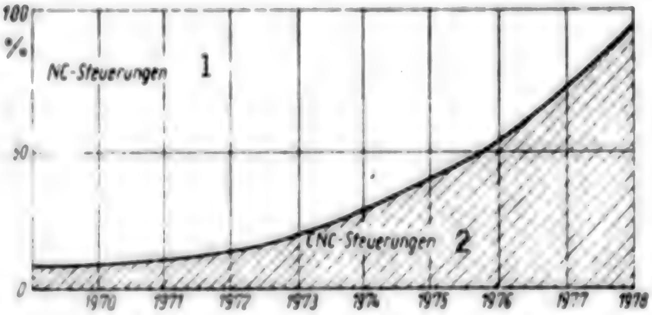


Figure 1: Proportion of CNC in the Total Number of Exhibited NC on International Technical Exhibitions

Key:

1. NC controls 2. CNC controls

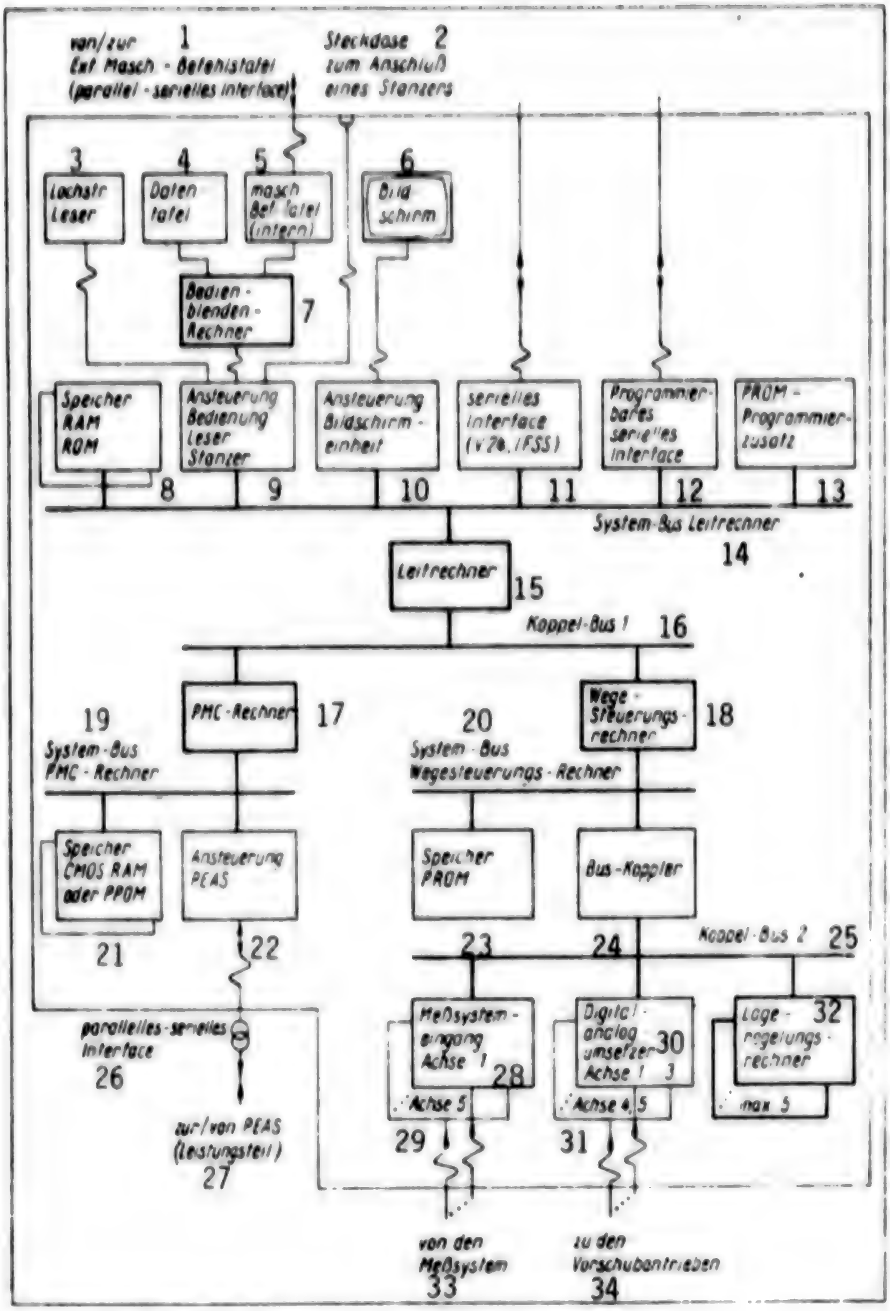

von/zur 1
Ext Masch - Befehlstafel
(parallel - serielles interface)
Steckdose 2
zum Anschluß
eines Stanzers
3 Lochstr Leser
4 Daten tafel
5 masch Bef tafel (intern)
6 Bild schirm
Bedien - blenden - Rechner 7
Speicher RAM ROM 8
Ansteuerung Bedienung Leser Stanzer 9
Ansteuerung Bildschirm - einheit 10
serielles interface (V 24, IFSS) 11
Programmier - bares serielles interface 12
PROM - Programmier - zusatz 13
System-Bus Leitrechner 14
Leitrechner 15
Koppel-Bus 1 16
PMC - Rechner 17
Wege - Steuerungs - rechner 18
19 System - Bus PMC - Rechner
20 System - Bus Wegesteuerungs - Rechner
Speicher CMOS RAM oder PROM 21
Ansteuerung PEAS
22
Speicher PROM
Bus - Koppler
23
24
Koppel - Bus 2 25
parallelles - serielles Interface 26
zur/von PEAS (Leistungsteil) 27
Meßsystem - eingang Achse 1 28
Achse 5
29
Digital - analog umsetzer Achse 1 3 30
Achse 4, 5
31
Lage - regelungs - rechner 32
max 5
von den Meßsystem 33
zu den Vorschubantrieben 34

Figure 2: Signal Flow Chart CNC 600 (1)

Key:

1. From/to external machine instruction table (parallel-series interface)
2. Plug for connecting a puncher
3. Paper tape reader
4. Data table
5. Machine instruction table (internal)
6. Display screen

Key (Continued)

7. Operating console computer
8. RAM, ROM memory
9. Control, operation, reader, puncher
10. Control, display screen unit
11. Serial interface (V24, IFSS)
12. Programmable serial interface
13. PROM programming supplement
14. System bus control computer
15. Control computer
16. Coupling bus 1
17. PMC computer
18. Path control computer
19. System bus PMC computer
20. System bus path control computer
21. Memory CMOS RAM or PROM
22. Control PEAS
23. PROM memory
24. Bus coupler
25. Coupling bus 2
26. Parallel-serial interface
27. To/from PEAS* (control part)
28. Measuring system input axle 1
29. Axle 5
30. Digital analog converter axle 1...3
31. Axle 4, 5
32. Position regulation computer
33. From the measuring system
34. To the positioning drives

---

*PEAS (Process Input/Output Control)

The tool machine industry of the GDR likewise follows this trend. At the present time, 40 types of NC machines are being produced. Several of these have already been equipped with the new CNC 600 control. This control system works on the basis of microprocessors. It was developed through the collaboration of the combines and enterprises of the Ministry for Electrical Engineering and Electronics, the Ministry for Tool and Processing Machines, as well as the colleges of the GDR.

1. Structure of the CNC 600

The CNC 600 is constructed according to the multiprocessor design. The signal flow chart (Figure 2) shows that the functions of the CNC have been distributed among several microcomputers. This achieves a modular structure both in the hardware and software, which depends on the number of axles being controlled.

Development concentrated especially on simplifying the programming of the workpiece. The programming of the workpiece was significantly facilitated by an extensive subprogram technique, by possibilities of quick correction, and by optimization of the NC component program by means of the built-in display screen and the alphanumeric keyboard. Furthermore, elements of computer-supported programming were included in the system software of the CNC 600.

2. New Characteristics of the CNC 600 With Workpiece Programming

Figure 3 shows an example of performing mathematical calculations through the CNC control. What is to be defined is the midpoint (Q_1, Q_2) of the large boring, a quantity which is obtained from the intersection of two circles (PKK). First of all, the intersecting circles must be described by their centers and radii. In the present case, two intersections may occur, and consequently the desired intersection must be characterized by a modifier. In the example, this is the VKL modifier (vertical smaller), which characterizes the desired solution. The calculated point can again be selected by the addresses Q_1 and Q_2 during the further run of the program. The specific numerical values are already calculated when the workpiece program is read in, and are stored in the component program memory. The computational directives therefore do not load the component program memory.

More than 100 technical and geometric subprograms were developed to simplify manual programming still further. The user can select such programs as necessary for his problem. These subprograms can be s [illegible] in the CNC 600. Furthermore, the user can develop and store his own subprograms.

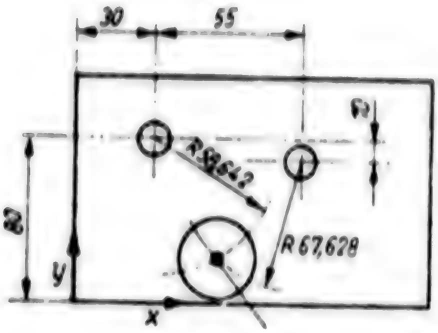


Figure 3: Example for Executing Mathematical Calculations by the CNC 600

```
PKK, 30,80,58,642/85, 70,67,628/VKL/
Q1, Q2
N 86 X = Q 1, Y = Q 2, L81...
```

PKK point, defined as the intersection of two circles
VKL vertical smaller

Depending on storage capacity, several workpiece programs can be stored and can be called in accord with the planned execution. Altogether, 80 m of paper tape can be stored.

Point-, straight line-, and circle-programs are taken over by the computer-supported programming and are integrated components of the CNC control.

The programming systems AUTOTECH-BOFR 3 and -DR 4 are the basis for the computer-supported programming of the tool machines with the CNC 600 control. These programming systems are already widespread in the GDR. They are implemented on the minicomputer KRS 4201, which has a storage capacity of 16 K words, with 16 bits each. About 30 percent of all control paper tapes for NC machines were programmed with AUTOTECH-BOFR 3 and -DR 4 during 1978. The programming languages BOFR 3 and DR 4 have now been expanded in such a manner that CNC machines can be effectively programmed and that the application of the macro technique is guaranteed. The macrotechnique greatly simplifies the description of recurring workpiece elements. Macros designate sections of the source program which are characterized by an identifier, are stored in a library, and are processed when the identifier is called. They are adapted to the prevailing conditions by current parameters. The macrotechnique will be explained through the example of processing a boring by centering, boring, countersinking, and reaming. (Figure 4). The workpiece shown in the figure receives eight similar borings. The macro instruction is set up for processing them (table).

By using these advantageous possibilities for component programming, the paper tape is shortened to about 40...50 percent as compared to previously used controls.

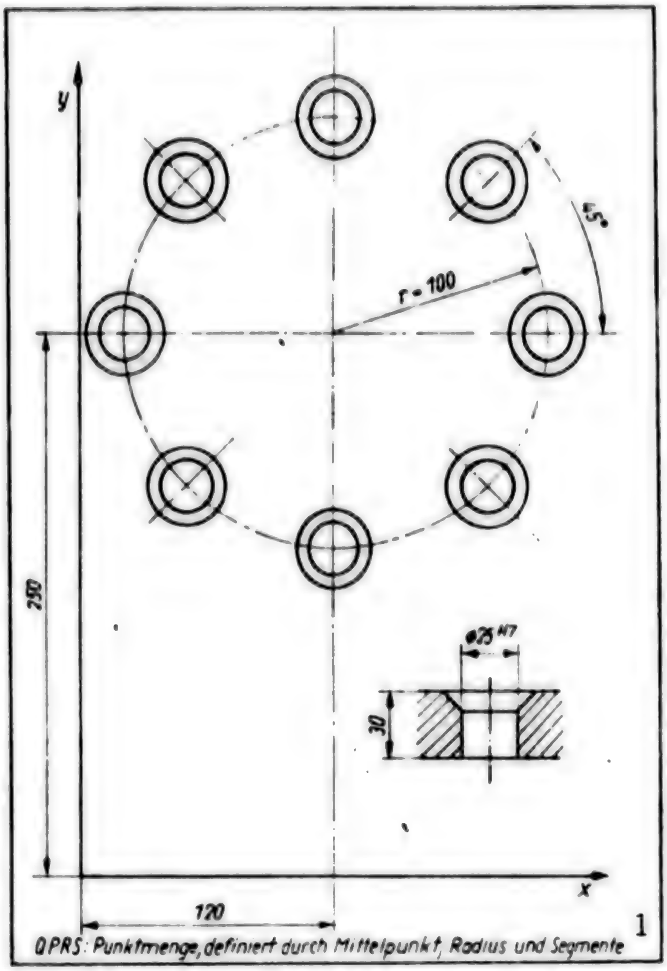
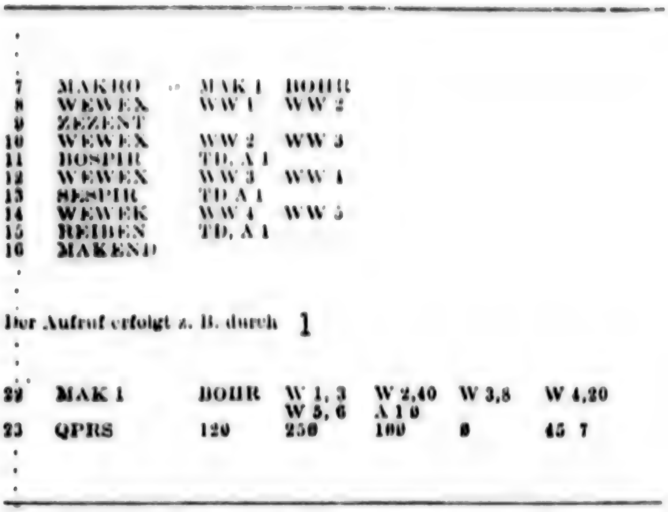

y
45°
r = 100
250
Ø25 H7
30
x
120
1
QPRS: Punktmenge, definiert durch Mittelpunkt, Radius und Segmente

Figure 4: Application of the Macro Technique

Key:

1. QPRS: Point set, defined by the center point, radius, and segments.



```
 .
 .
 .
 7   MAKRO   =  MAK 1   BOHR
 8   WEWEX      WW 1    WW 2
 9   ZEZENT
10   WEWEX      WW 2    WW 3
11   BOSPIR     TD, A 1
12   WEWEX      WW 3    WW 4
13   SESPIR     TD A 1
14   WEWEK      WW 4    WW 5
15   REIBEN     TD, A 1
16   MAKEND
 .
 .
 .
Der Aufruf erfolgt z. B. durch  1
 .
 .
 .
22   MAK 1       BOHR   W 1, 3   W 2,40   W 3,8   W 4,20
                        W 5, 6   A 1 0
23   QPRS        120    250      100      0       45  7
 .
 .
 .
```

Table: Structure of a Macro Instruction

Key:

1. The call is effected e.g. by

3. Delimitation of Manual and Machine Programming

In connection with the freely programmable controls, the question is often raised concerning the delimitation of the application areas between manual and machine programming. In the FCW (Research Center for Tool Machine Construction), an attempt was made to compare the costs for manual and machine control programming. With application to an arbitrary user operation, the following criteria were developed as the most important ones:

The total number of control programs required

The average number of control program sets

Costs for purchasing the programming system (processor and postprocessors).

With the result that is subsequently presented, the following assumptions were made:

AUTOTECH-BOFR programming system

Minicomputer system KRS 4201 with standard peripheral equipment

Production time determination required in about 40 enterprises; experiential data obtainable for

Computer times

Programming times (source program and control program)

- Coding times for the production of paper tape
- Production time determination

Composition of parts assortment

- 90 percent point-line control problems
- 10 percent path control problems.

The following factors were taken into account in making the cost comparison:

- Costs for working out the source or respectively the control program
- Coding costs
- Computer costs
- Costs for program execution
- Costs for production time calculation.

If the control program costs of manual programming are set equal to those of machine programming, and if the above assumptions are taken into account, the result is the limit curves shown in Figure 5. Figure 5 shows that the application area of machine programming becomes all the larger, the larger is the number of control programs required, the larger is the average complexity of the workpiece, and the smaller are the acquisition costs of the required computer programs.

4. Programmable Machine Adapter PMC 600

The programmable machine adapter control will be explained below.

The CNC 600 contains, as standard equipment, a programmable machine adapter PMC 600. The hardware of this unit has been split into two parts. The first part is built into the cabinet of the CNC 600 and comprises the PMC microcomputer, a semiconductor memory for storing the machine adapter program in the form of Boolean equations, and the interface card module for controlling the so-called PEAS (Figure 2). The second part, the PEAS, is built into the power switch cabinet (Figure 6). The PMC 600 is connected with the NC control computer through an internal data box, the coupling bus 1. It is consequently capable of processing not only machine signals but also information from the NC control computer, and of transmitting information to the latter. The PMC control unit consists of the single-card computer K 2521. It handles the logical processing of inputs and outputs to and from the machine as well as to and from the NC, in accord with a linkage directive which is present in the memory in the form of Boolean equations. This linkage directive is worked out and tested

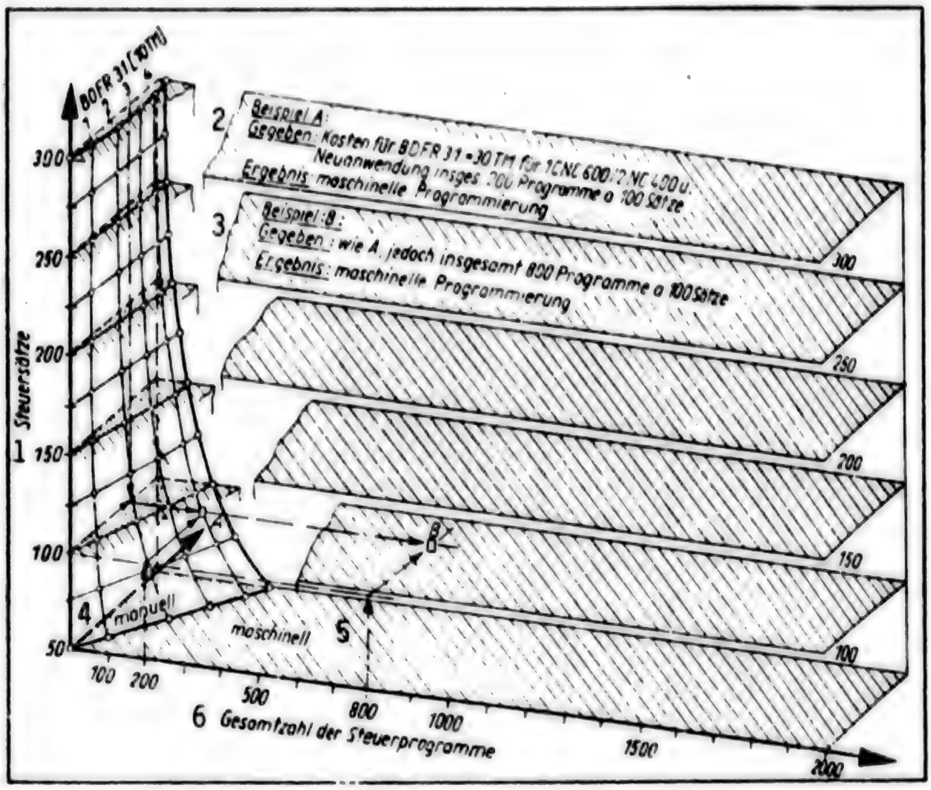


Figure 5: Programming Areas of the CNC 600 (Intense Preparatory Production)

Key:

1. Control Records
2. Example A:
   Given: Costs for BDFR 31 = 30 TM for 1 CNC 600/2 NC 400 and new application of a total of 200 programs with 100 records each
   Result: Machine programming
3. Example B:
   Given: Like A, but a total of 800 programs with 100 records each
   Result: Machine programming
4. Manual
5. Machine
6. Total number of control programs

by the user of the PMC 600, i.e. by the machine manufacturer. The PMC also implements timing elements and takes over special functions for controlling the main drive and the positioning of the tool memory. Other routine programs take over the data transfer to the NC through the coupling bus 1 and to the PEAS through the PMC bus.

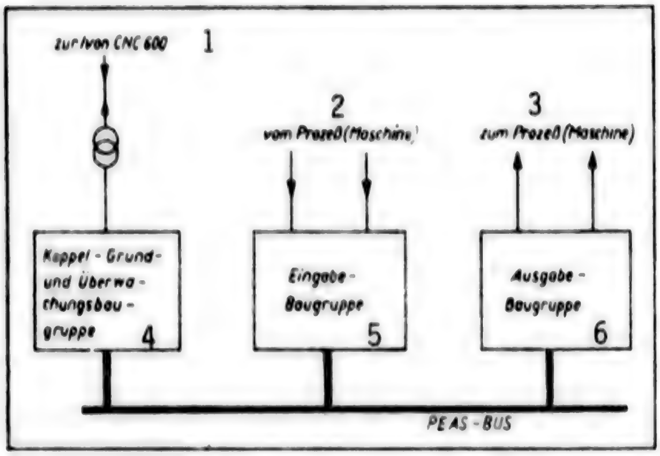


Figure 6: Signal Flow Chart of the Process Input/Output Control (PEAS)

Key:

1. To/from CNC 600	4. Coupling- ground- and monitoring module
2. From the process (machine)	5. Input module
3. To the process (machine)	6. Output module

These operating programs are stored in the PROM area of the single-card computer. During the start-up phase, the user program is stored in the battery-supported CMOS-RAM (maximum 12 K bytes). After the start-up phase is completed, it is changed over to the PROM.

The card module AS-PEAS implements a series-parallel interface 26 bits wide. This makes it possible to connect 50 m cables and contains the DC isolation of the PMC central unit and the PEAS.

The input/output block PEAS can accept not only a basic complement of three card modules but also 20 input/output card modules. It can therefore process on the average 240 machine signals. By connecting an expansion cassette, up to 480 machine signals can be processed. The PEAS switches through the input/output signals, which are ordered according to channels; it amplifies the output signals to the required level for directly controlling positioning elements; and it adapts the input signals to the internal level.

The PEAS comprises a complete system of diagnostic and monitoring devices. When an error occurs, the monitoring devices switch the control into a state that is without danger for the machine and the operator. The diagnostic equipment uses test programs to find the defective card module. The programmable machine adapter control is constructed in such a way that no additional programming unit is required for setting up or changing the program!

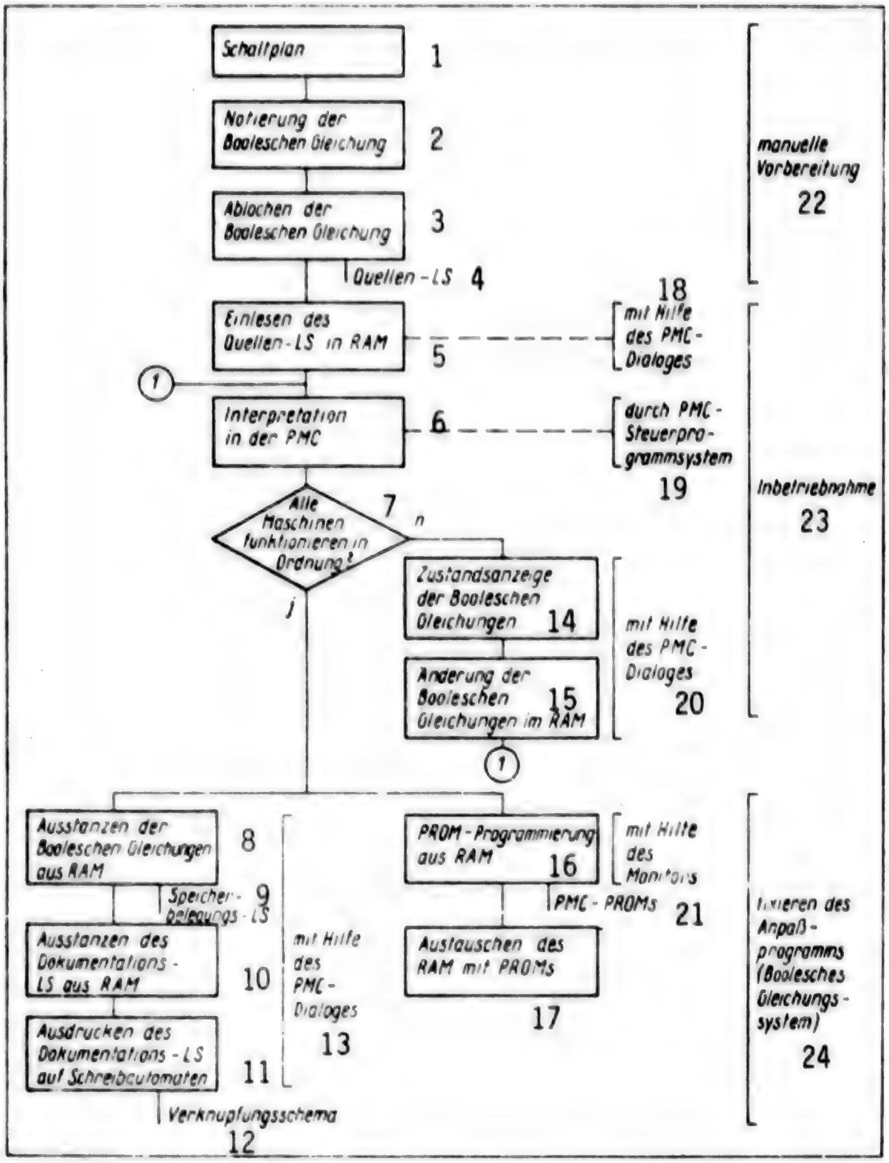

Schaltplan 1
Notierung der Booleschen Gleichung 2
Ablochen der Booleschen Gleichung 3
Quellen-LS 4
Einlesen des Quellen-LS in RAM 5
18 mit Hilfe des PMC-Dialoges
1
Interpretation in der PMC 6
durch PMC-Steuerprogrammsystem 19
Alle Maschinen funktionieren in Ordnung? 7
n
j
Zustandsanzeige der Booleschen Gleichungen 14
Änderung der Booleschen Gleichungen im RAM 15
mit Hilfe des PMC-Dialoges 20
1
manuelle Vorbereitung 22
Inbetriebnahme 23
Ausstanzen der Booleschen Gleichungen aus RAM 8
Speicherbelegungs-LS 9
Ausstanzen des Dokumentations-LS aus RAM 10
Ausdrucken des Dokumentations-LS auf Schreibautomaten 11
Verknüpfungsschema 12
mit Hilfe des PMC-Dialoges 13
PROM-Programmierung aus RAM 16
mit Hilfe des Monitors
PMC-PROMs 21
Austauschen des RAM mit PROMs 17
fixieren des Anpaßprogramms (Boolesches Gleichungssystem) 24

Figure 7: Steps Necessary to Solve the Adaptation Problem (1)

Key:

1. Switching plan
2. Notation of Boolean equations
3. Punching the Boolean equations
4. Source paper tape
5. Reading the source paper tape into the RAM
6. Interpretation in the PMC
7. Are all machine functions in order?
8. Punching out the Boolean equations from the RAM
9. Storage allocation paper tape
10. Punching out the documentation paper tape from the RAM
11. Printing out the documentation paper tape on automatic writing units
12. Linkage schema
13. By means of PMC conversational mode
14. Status indication of Boolean equations
15. Changing the Boolean equations in the RAM
16. PROM programming from the RAM
17. Replacing the RAM with the PROM's
18. By means of PMC conversational mode
19. Through the PMC control program systems
20. By means of PMC conversational mode
21. By means of the monitor
22. Manual preparation
23. Start-up
24. Fixing the adapter program (Boolean system of equations)

5. Working Out the Machine Adapter Program for the PMC 600

The steps required for setting up the machine adapter program, for troubleshooting, and for documentation are shown in Figure 7.

The individual steps are explained in more detail below.

The tool machine manufacturer need only set up the linkage conditions of the switching elements in the form of Boolean equations, in order to program the PMC. The Boolean equations can be derived from

the relay diagram,
the flow charts or
description of linkage conditions in verbal form.

Experience has shown that electrical engineers in tool machine enterprises master Boolean equations just as reliably as the previously customary technique of relay symbols. The equations are punched on paper tape, and this completes the first phase of programming for the PMC.

When the tool machines are started, the resulting source paper tape is read into an RAM memory of the PMC, with the CNC control, through a paper tape reader of the CNC 600. This RAM is plugged in only during the start-up phase, and is later replaced by a PROM, when all interlock conditions have been tested. During start-up and testing of the machine and of the control, the condition of the variables in the Boolean equation can be indicated by means of the alphanumeric keyboard and display screen which are available in the CNC 600. Furthermore, variables or entire equations can be changed, deleted, or added. A service program, the so-called PMC conversational-mode program, is read into the workpiece programming memory of the CNC 600, for starting up and testing the system of equations. The transfer structure of the PMC program facilitates segment-by-segment start-up of the system of equations. The PMC operating program furthermore permits calling its own assembler programs and special programs, which cannot be described by Boolean equations, e.g. the program for tool change, or automatic transmission change in the main drive, depending on the programmed speed.

After the testing phase has been concluded, the system of equations can be outputted on a paper tape puncher, which can be connected to the CNC 600. By means of the service program DOK 600, a paper tape can be punched, which will generate a stylized relay diagram for documentation purposes, when it is inserted into an automatic writing device.

As a supplement, the CNC 600 has a plug-in unit for programming the PROM from the RAM of the PMC. Programming the PROM is supported by the program "Monitor", which can likewise be read into the CNC as a service program. After the PROM programming, the RAM can be replaced by the PROM.

The tool machine manufacturers lay special stress on programmable fault indications of machine conditions. For this purpose, various signals from the machine and from the control are logically connected together, in such a way that error messages can be derived therefrom. These error messages are indicated on the display screen, or they can also be used for the programmed shutdown of the tool machine.

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GERMAN DEMOCRATIC REPUBLIC

TRENDS IN ELECTRONIC MEASUREMENT TECHNOLOGY DEVELOPMENT DISCUSSED

East Berlin FEINGERAETETECHNIK in German Vol 28 No 10, Oct 79 pp 462-468

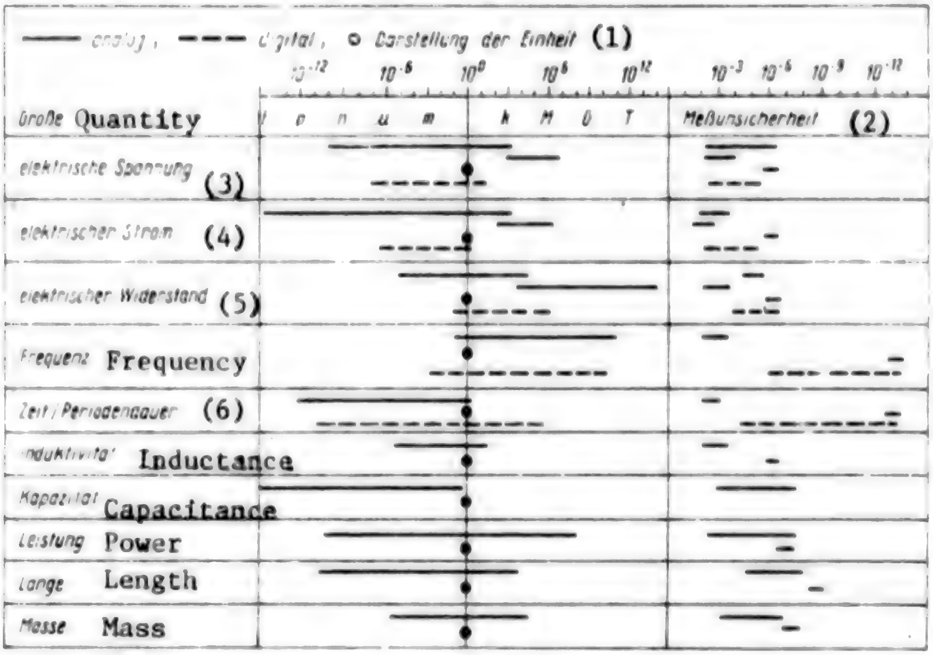
[Article by Prof Dr. U. Fruehauf, engineer, Information Technology Department, Dresden Technical University: "Development Trends of Electronic Measurement Technology." A translation of the article cited in footnote 21 is published in JPRS 74512, 5 November 1979, No 651 of this series, pp 16-25]

[Text] The fulfillment of the social goal of boosting the quantitative and qualitative level of production presupposes, among other things, the continually more efficient recognition and mastery of scientific and production engineering relationships. Measurement technology makes a decisive contribution here in close cooperation with other technical disciplines. The control and optimization of processes is based on precise knowledge of the interrelationships at work in the existing state of affairs. The methods and principles of electronic measurement engineering are of particular significance in this case, i.e., the operational electronic principles used for the measurement of the characteristic quantities of signals and systems, where these principles find application, for example, in voltage, time and frequency, and oscillograph or component measurement equipment.

The Tasks of and the Requirements Placed on Laboratory and Production Measurement Engineering

Laboratory measurement technology makes the metrological principles, research and developmental aids, and to a certain extent, also methods and facilities available for the quality and reliability testing of materials, components and products. The predominant orientation in the equipment used for this purpose is towards the assurance of measurement precision. In production measurement technology, functional reliability, economy and special problems of application (environmental conditions, climate, explosion proofing, automation capability) are the center of attention. The extreme value ranges of physical quantities do not predominate in the instrumentation, and it is largely the compatibility of the equipment in the measurement signal and information channel that is of particular interest. The latter requirement is also gaining importance now in laboratory measurement technology and influences, besides the economics, also the attainable state of the art in the registration of a multiplicity of measurement quantities. Table 1 depicts in which value range the determination of individual quantities has been mastered in the laboratory or at an engineering level ([1] to]4]). The quantities measured by electronic means are, for this reason, of particular technical interest, because in general, the nonelectrical quantities (for example, those of process instrumentation) are determined via their conversion to a voltage, frequency, time or resistance which is proportional to them. Measurement data processing, for example, for process control, today entails predominantly the evaluation of electronic analog quantities. The state of the art and developmental trends in electronic measurement technology thereby also have an influence on other disciplines.

Table 1. The Mastered Range of Values of Selected Measurement Quantities



Key: 1. Representation of the unit;
2. Measurement uncertainty;
3. Electrical voltage;
4. Electrical current;
5. Electrical resistance;
6. Time/period duration.

Fundamental Developmental Trends

The close interdisciplinary interweaving of the various fields of science and engineering is a basic feature of the present state of development, which is especially pronounced in measurement technology. Thus progress in electronics in the manufacture of components and functional units with a high level of integration and considerable functional density, as well as with lower power consumption and an increasing gain-bandwidth product is a prerequisite for the design of new kinds of high performance measurement equipment. Figure 1 clearly shows in which way equipment construction, measurement technology and other fields of science and engineering are experiencing a considerable stimulation of the development through the possibility of the use of modern components. Modern findings in signal and systems theory [5], [6], including error theory [7], stochastics [8] and [9], and their incorporation in the solution of measurement engineering problems are the theoretical foundations for this modern equipment. On the other hand, these increased measurement engineering capabilities make it possible to come up with new scientific findings and manufacture modern complex electronic components, functional units and systems both efficiently and well. In this case, it is not solely the extension of the parameter range for measurement equipment which is of decisive importance, but rather the application of newer more effective principles, which provide the capability of determining optimal signal or system characteristic quantities and measurement data processing. It is specifically the inclusion of functional computing components that has decisively influenced the development of electronic measurement engineering in the last 10 years and brought forth a

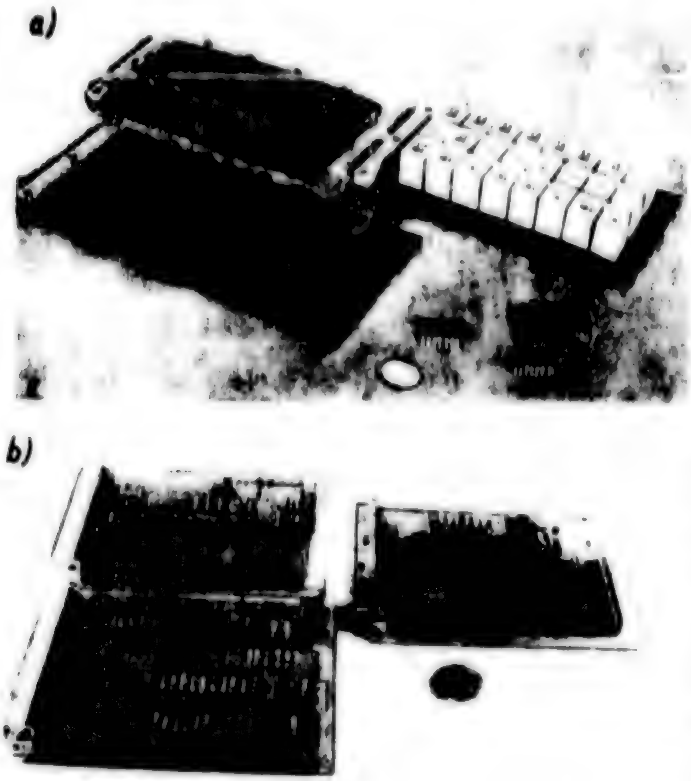


Figure 1. Examples of the development of electronic circuits in measurement equipment.

a) Decade counters in a discrete circuit design; shift registers of a modular design (1960-65); hybrid circuit engineering (1965-75); microelectronics for multiple gates and memory circuits.
b) Printed circuit boards for measurement data processing with microcomputers (1978-79).

qualitatively new group of measurement equipment: so-called intelligent measurement equipment. In this way, the initial prerequisites have been created for the providing of adaptive measurement systems. Through the application of modern integrated functional components, such as microprocessors, storage circuits, or in the near future, the incorporation of single chip computers in measurement equipment, the goal of the measurement of selected parameters using optimal strategies will become attainable. attainable.

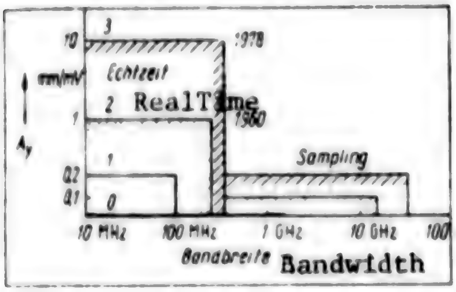


Figure 2. The state of the art in oscilloscope design as a function of the state of the art in component design (0: oscilloscope tubes; 1: oscilloscope of vacuum tube design; 2, 3: oscilloscope of semiconductor design.

The interrelationships presented here are to be considered in more detail using the example of oscilloscope measurement technology: it turns out that the transition from vacuum tubes to transistors at the start of the 1960's decisively influenced the upper cutoff frequency and sensitivity (Figure 2). The development of the following years, on the other hand, was expressed less in a substantial improvement in the parameters than in a remarkable expansion of functions. The processing block has been added to the basic unit and the input units (input amplifiers) of the "classical" oscilloscopes. It performs the signal processing and controls the functioning of the equipment via microprocessors or computers. The development of other electronic measurement systems is running a similar course. The progress made, such as smaller equipment volumes and lower energy consumption with the same or increased operating conveniences, connection capabilities for further equipment via standardized information channels (interfaces), among other things, was achieved through the use of improved and new electronic components in conjunction with a modern system design. This is particularly pronounced in the conceptual and technical configuration of the components of the processing unit. Modular construction (Figure 3) is a basic prerequisite for the realization and application of modern, high performance and economical measurement installations. For example, it also finds advantageous applications in harmonic measurement systems, voltage measurement equipment and in minicomputers.

The Use of Microelectronic Components

Semiconductor components are used practically without exception now in measurement technology. Only in a few cases are some vacuum tube components still being used (oscilloscope tubes, special radiation protectors, gas protected relays). The vacuum tube has also been replaced by the field effect transistor where for a long time it occupied a dominant and seemingly uncontested position of predominance because of its high input impedance. Input impedances of from about 10^9 to 10^{12} ohms are being achieved with modern field effect resistors, especially, with MOS field effect transistors, and the requisite overvoltage immunity is being achieved through special protective circuits. Voltage measurement equipment and amplifiers today exhibit input impedances of from a few hundred megohms up to a few hundred teraohms [10^{12} ohms]. While in 1974 the input impedances of operational amplifiers of a semiconductor modular design could only be brought up to 10^4 to 10^6 ohms, today 10^{10} to 10^{12} ohms are typical values through the use of MOS field effect transistors (also double MOSFETs). Other parameters of operational amplifiers series produced as functional units have also been improved at the same time. This is expressed in a reduction of the offset current by about a factor of 10 to 100, in an increase in the bandwidth and the voltage rise (v/μs) by a factor of 3 to 10 ([10], and others). In the case of special subassemblies (hybrid technology, BiMOS technology or modular construction), values of about an order of magnitude better have been achieved.

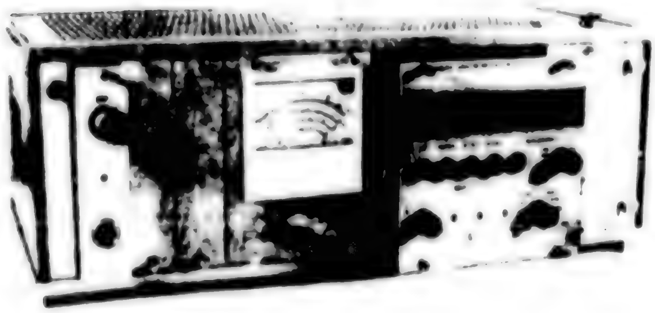


Figure 3. Example of modular technology.

In analog measurement equipment, because of the limited resolution of the readout instruments, in general measurement data of from 7 bits to a maximum of 10 bits could be registered (measurement error of 1% to .1%). The widely used operational amplifier types are applicable here. They are also finding application as input amplifiers for digital measurement equipment. Their combination with integrated analog to digital converters (for example, in one housing) as a functional unit for 8 to 10 bits and conversion times in the range of a few microseconds (a conversion rate of [illegible] is typical). A remarkable feature of these components in single chip technology (I^2L technology, 16 pin DIP without the readout section) [illegible] the low power consumption (about 50 mw), the possible automatic polarity and over-range indication and an error of from ±0.1% of full scale, ± 1 digit. A comparison of the principles developed for digital voltmeters and the functional groups necessary for them ([2], [11] to [13]) with the capabilities of integrated circuit engineering clearly shows that the realization of so-called one chip digital voltmeters is technologically feasible. In this way, not only is a high performance subassembly available for measurement equipment, but this one-chip digital voltmeter is to be viewed as an example of the evolution of functional electronics. Presently, 8 to 10 bit analog to digital converters are finding widespread use. The 12 and 14 bit IC converters (predominantly hybrid technology) are relatively new on the international marker; they will likewise have impact on the further development of computer controlled measurement equipment and measurement data processing. A conversion time below 1 µsec is to be expected by 1980 (at the present time, 2 to 200 µsec for 12 bit analog to digital converters).

The same developmental trends basically apply for digital to analog converters, since they generally contain the same kind of functional groups. At the present time, the first 18 bit digital to analog converters are appearing as a modular unit [14] (10 and 250 µs conversion time for a current and/or voltage output; I_a = 0 to 2 ma for -1 to +1 ma; U_a = = -5 to +5 volts or -10 to +10 volts). Thus, the basic prerequisites are present for the development of measurement equipment, systems for information processing and equipment systems based on the functional block principle. In general, only special subassemblies which must process extreme value ranges are also manufactured using discrete technology in instrument engineering (for example, special input stages), while the effort is made to solve subsequent information and measurement data processing problems through the use of functional electronic components.

As regards the maximum processable information flow of about 20 Mbit/sec (Figure 4), both analog to digital and digital to analog converters fall between the analog and digital integrated circuit in terms of their performance. The conversion time and maximum amount of information are basically determined by the analog operating parts of these integrated circuits. In the case of analog integrated components, an information flow of from 10 to 100 Mbit/sec has been technically mastered (operational amplifier: 1 to 50 Mbit/sec; comparator: > 10 Mbit/sec). In contrast, this value falls between 100 and $50 \cdot 10^3$ Mbit/sec for digital circuits. With discretely constructed analog circuits, or discrete individual components (transistors, diodes), information flows of from 100 to $10 \cdot \cdot 10^3$ Mbit/sec are realized simply, so that for fast and precise digital measurement equipment, the analog input circuits are constructed in the overwhelming majority of cases using discrete or hybrid circuit technology (for example, scanning and latching circuits, fast input amplifiers, fast analog to digital converters with 6 to 8 bit/10^8 conversions ≈ 800 Mbit/sec). A continual increase in the precision in the manufacture of analog integrated circuits will lead to even better values. At bandwidths of about 50 MHz and an information volume of 16 bits, the information flow in analog systems reaches such a value (1,500 Mbit/sec), that even with digital measurement equipment, analog measurement data processing and information compression are already becoming technically interesting in the input section. At the present time, the attainable maximum information flow in the case of integrated scanning and latching circuits falls around 500 Mbit/sec (measurement errors of less than 0.01% at a

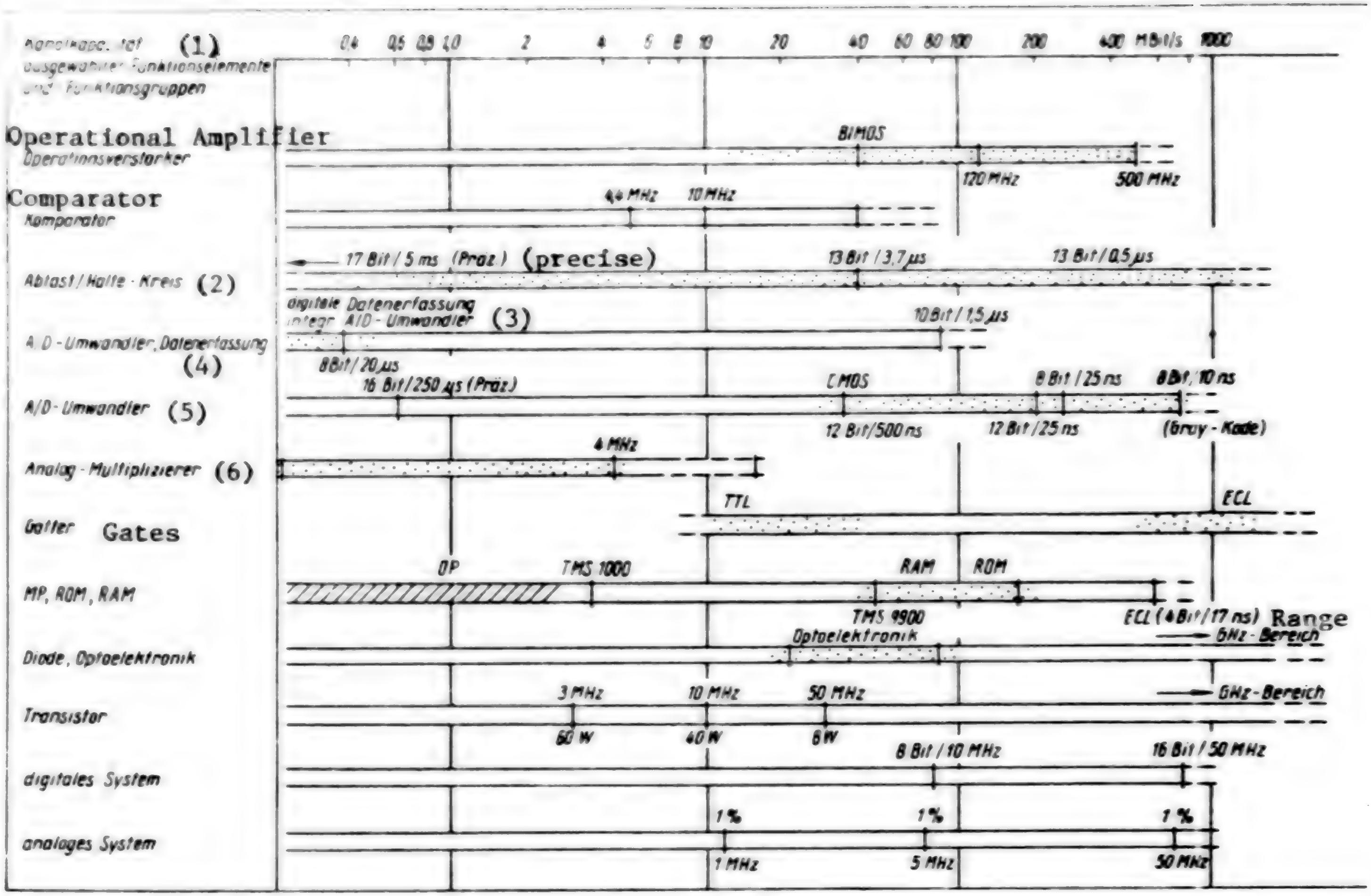


Figure 4. Overview of the information flow in selected functional components and systems in measurement engineering (the fifth concept must read D/A converters).

[Key to Figure 4]:

1. Channel capacity of selected functional components and functional groups;
2. Scanning/latching circuits;
3. Digital data acquisition, integrated analog/digital converters;
4. Analog to digital converters, data acquisition;
5. Analog to digital converters [sic];
6. Analog multipliers.

switching frequency of 20 MHz), and around 1,200 Mbit/sec in the case of analog multipliers (measurement errors of less than 2%, bandwidths of 100 MHz). Digital measurement engineering is given considerable impetus through the application of switching, store and computer circuits developed for digital computer engineering, in which case, the difference between analog and digital technology is not significant in terms of information processing. However, digital storage circuits are far superior to the analog circuits for the storage of measurement data. The trend in digital technology is towards large scale integration. At the present time, about $40 \cdot 10^3$ transistors are being placed on one semiconductor chip in production processes. An increase in the level of integration to 10^5 to 10^6 transistors per chip is forecast for 1981/82 through a further reduction in the size of the structures on the chip, with only a slight increase in the chip size. At the same time, this progress is being made by means of the transition from two-dimensional to three-dimensional structures.

Delay lines, multiplexers, multipliers and adders can be built on the basis of CCD technology (charge coupled device [15]), for which an operational speed of 10^9 multiplications per second is anticipated. CCD memories, for example, as a buffer between main memeories and data files, at the present time have data rates of from 1 to 5 Mbit/sec at 64 Kbits (access time of 0.121 msec). Memory units of 264 Kbits will become a technical reality in the near future.

For measurement technology, the tendency in the case of integrated circuits is towards the continually reducing number of technological steps and the largely computer supported circuit design. In this way, the manufacture of the requisite multiplicity of integrated circuits in measurement engineering will be economically feasible with a relatively small number of units (Figure 5a) [16]. No redemption of analog technology is to be anticipated by digital circuit technology, but rather a combination, a stronger cooperation between analog and digital circuits in a measurement system. Figure 5b illustrates the timewise development of the integration level (bits per chip) and the price for memory circuits. Equally valuable data are available for other components.

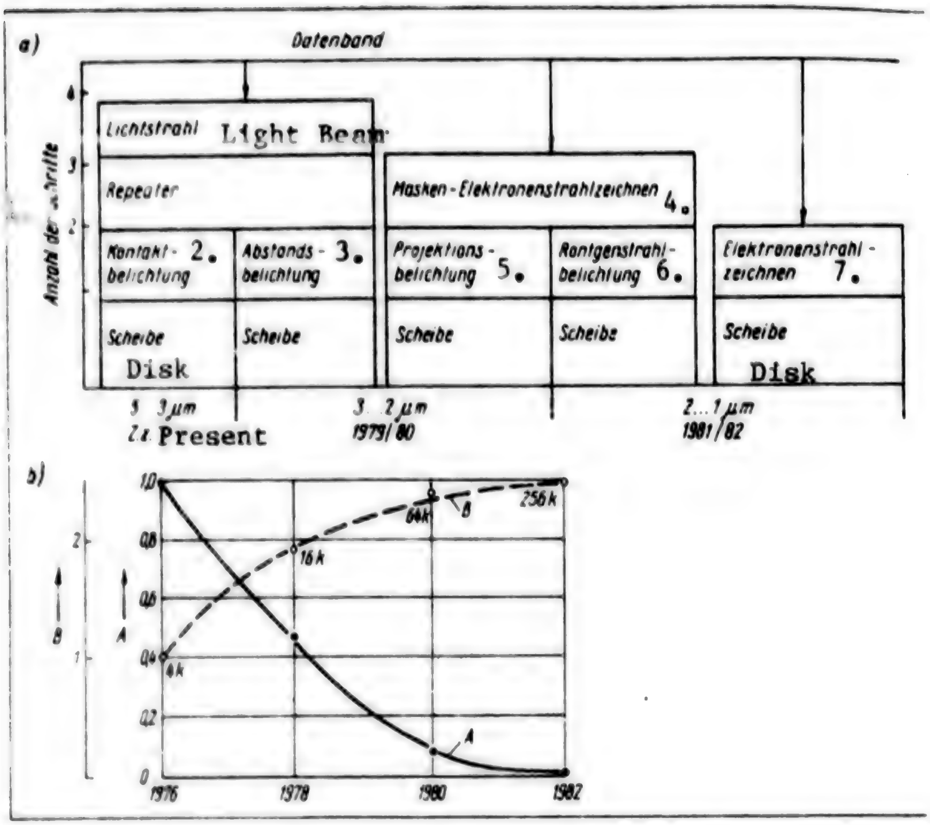


Figure 5. Development of integration technology.

a) Number of necessary technological steps;
b) Costs per bit (A) and component price (B).

Key:
1. Number of steps;
2. Contact illumination;
3. Separation space illumination;
4. Masks - electron beam drawing;
5. Projection illumination;
6. X-ray illumination;
7. Electron beam drawing.

Through the combined use of analog and digital subassemblies, new functional principles principles can be realized, with which the specific drawbacks of individual circuit components and subassemblies can be compensated. New types of system concepts are arising. For example, besides the technical realization of effective interfering voltage suppression through the utilization of the integrating time behavior of the counter components, the application of the averaging principle, of digital filters or correlation techniques, substantial improvements in system properties can be achieved with comparatively simple principles (Figure 6). Through the combination of analog circuits (whcih are hardly to be dispensed with in digital systems also), the result is a substantially improved immunity to amplifier drift and offset voltage (Figure 6a) by means of a special measurement strategy and an appropriate measurement data processing algorithm. Figure 6b shows how in a digital voltmeter, with a system design based on the principle of double integration (dual slope principle), the advantages of integration for interferint voltage suppression are achieved in clock period 1, and a digital display is made possible in clock period 2 by counting out the time interval T2. The control pulse for the integration interval T_1 and for the T_2 measurement are provided by the same generator, so that one generator alone with a high short term frequency stability (where $T_1 + T_2$ is a few tens of milliseconds!) must be employed. Then, for example, a crystal oscillator can be eliminated (which cannot be manufactured using integrated technology). All of the necessary subassemblies are amenable to integration, and digital voltmeters of this kind can likewise be realized on one chip.

The first 16 bit microprocessors are appearing for digital information processing units, and the first 32 bit microprocessors are expected for 1985. Here, one must take into account the fact that for the majority of technical factilities, the error limits in the future will also generally fall around 0.1 ... 0.01 ... 0.0015% (corresponding to an information volume of about 10 ... 14 ... 16 bits). Regardless of the special applications cases (precision measurement, 16 bit or 32 bit corresponding to a resolution of about $1.5 \cdot 10^{-5}$ or 2.5 to 10^{-10}, cf. Table 1, for example, in the case of frequency, time and length measurement), 32-bit processors will be of interest in measurement engineering, especially for rapid process control, in addition to measurement data processing. As regards the various types of microprocessors and technologies, and their developmental trends, we would refer here to the literature ([18], [19], etc.). The general trend of integrating not only subsystems, but also hardware and software on a silicon chip, will also be of importance for measurement technology.

Measurement Data Processing and Measurement Data Evaluation

The widespread use of microcomputers in measurement technology consists in their application as control and computer units in conjunction with modules and measurement equipment. The captions for Figure 6 illustrate that the incorporation of information processing subassemblies makes the technical realization of modern and high performance measurement system design possible. The programmability, measurement data processing, measurement sequence control as well as the man/measurement instrument communications are decisively improved through the use of microprocessors, digital memories and arithmetic structural units. Figure 7 shows the

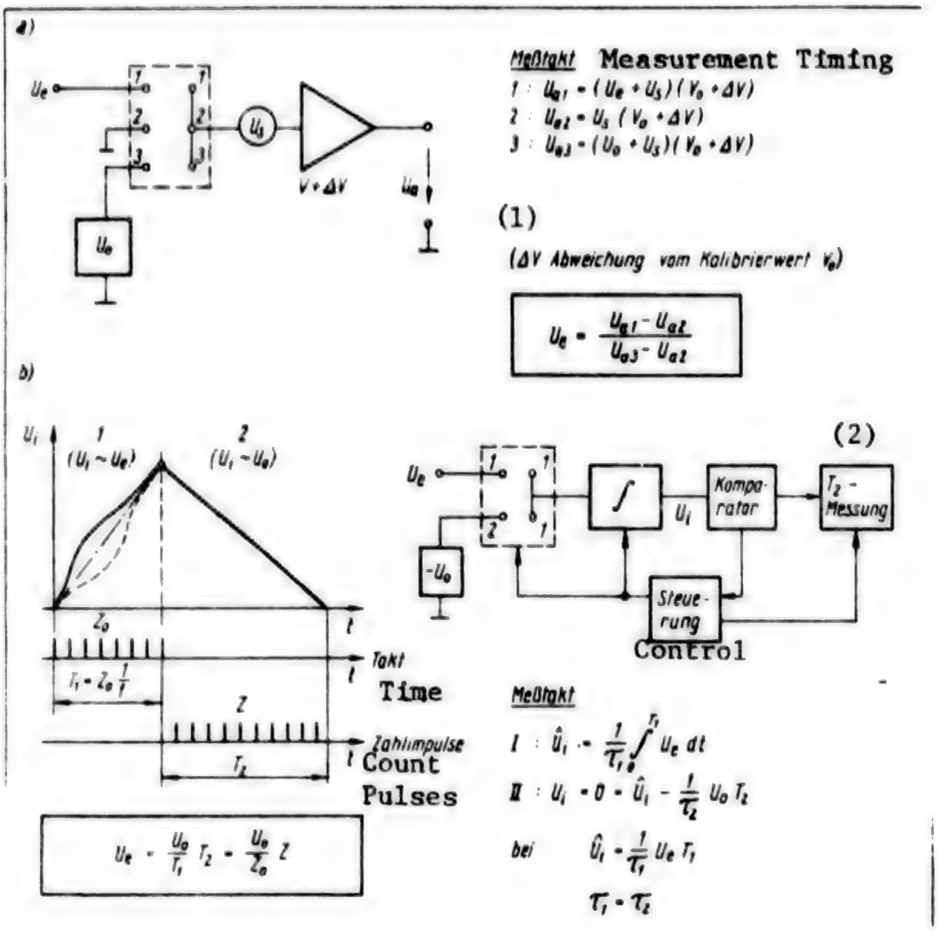

a)
Meßtakt Measurement Timing
1 : $U_{a1} = (U_e + U_S)(V_0 + \Delta V)$
2 : $U_{a2} = U_S (V_0 + \Delta V)$
3 : $U_{a3} = (U_0 + U_S)(V_0 + \Delta V)$
(1)
(ΔV Abweichung vom Kalibrierwert V_0)
$U_e = \frac{U_{a1} - U_{a2}}{U_{a3} - U_{a2}}$
U_e
U_S
$V + \Delta V$
U_a
U_0
b)
U_i
1 $(U_i \sim U_e)$
2 $(U_i \sim U_0)$
Z_0
Takt
Time
$T_1 = Z_0 \frac{1}{f}$
Z
Zählimpulse
Count Pulses
T_2
t
$U_e = \frac{U_0}{T_1} T_2 = \frac{U_0}{Z_0} Z$
(2)
$-U_0$
U_i
Komparator
T_2 - Messung
Steuerung
Control
Meßtakt
I : $\hat{U}_i = \frac{1}{\tau_1} \int_0^{T_1} U_e \, dt$
II : $U_i = 0 = \hat{U}_i - \frac{1}{\tau_2} U_0 T_2$
bei $\hat{U}_i = \frac{1}{\tau_1} U_e T_1$
$\tau_1 = \tau_2$

Figure 6. Examples of new system properties in the case of electronic measurement systems with the use of new system concepts.

Key: a) Automatic calibration;
b) Interfering voltage suppression and reduction of the influence of drift.
1) (ΔV, deviation from the calibration value, V_0);
2) T_2 measurement.

basic configuration of this kind of microcomputer utilized for intrumentation purposes. It consists essentially of the basic computer unit, which in general takes the form of a printed circuit board. It contains the central processor, the memory units, decoder, clock unit and driver. The performance of the components which are available is generally so high, that for many measurement instruments, the basic computer unit is sufficient for the solution of the problem (so-called single board computers). On the other hand, the scope of the system can be adapted to the complexity of the problem by means of expander circuit boards, without having to make hardware changes. This purpose is served by printed circuit boards for memory expansion, as well as circuit boards for input/output and interfacing with other equipment and modules. From a measurement engineering viewpoint, the following considerations are decisive in the outfitting of the basic computer unit with memories and input/output capability:

--Many measurement problems can be solved with just the basic unit, since the available memory capacity is frequently sufficient for simple measurement engineering problems (for example, a 1 Kbyte PROM, 0.5 Kbyte RAM).

--The requisite displays and inputs/outputs can be easily provided for the basic unit. Additional input/output capabilities are only required for extensive measurement and control problems, especially if the basic computer unit is not an integrated component of the automated "intelligent" measurement instrument, but rather serves as the nucleus of a control and computer unit (computer controlled measurement position).

--Memory expansion can be oriented to a specific problem.

--The basic computer unit usually has the capability of connecting a teletype and/or a display, so that this configuration can be used to enter programs, execute tests and read the memory and register contents. Data exchange with the measurement electronics is accomplished via the internal Bus in the case of intelligent measurement instruments, otherwise, via special connection control units.

An appropriate software is available for the evaluation and further processing of signals and measurement data by freely programmable digital computers and microprocessor systems, where the percentage of system costs comprised by the software is increasing continually (1950 about 15% and for 1985, about 80% is anticipated). The causes of this are the increasing demands on measurement data processing and evaluation programs, as well as the tendency towards simple signal scanning for the hardware solution of various complex measurement problems (simple measurement hardware) and the realization of more extensive data evaluation for this. In this way, the number of the different types of measurement instruments required falls off, while the requirements placed on their compatability in signal and information channels increase. Especially central control capability and data acquisition is of increasing significance for measurement processes.

At the same time, a certain trend towards decentralization is to be observed in measurement data processing. From a measurement engineering viewpoint, this development is expressed in increasing intelligence of the measurement equipment and measurement systems. The central controller

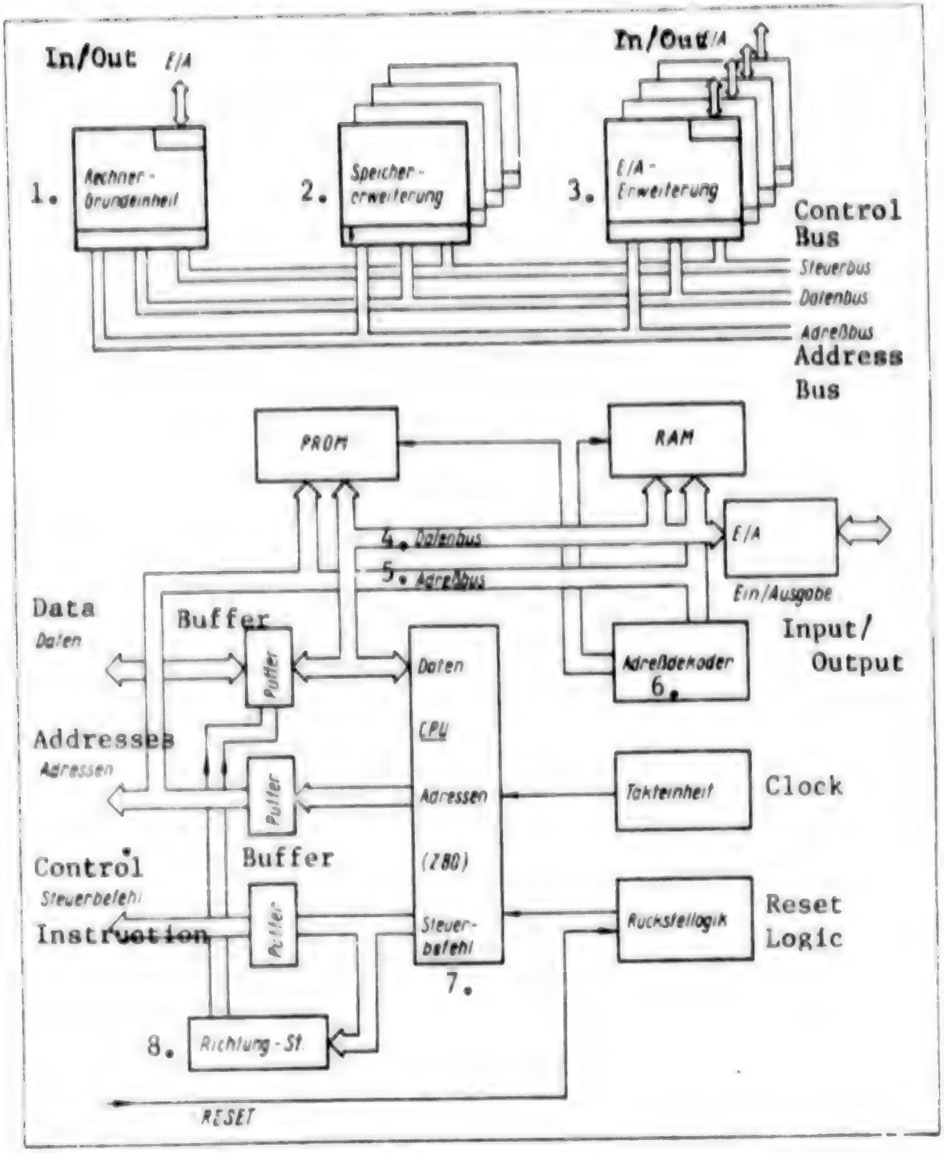
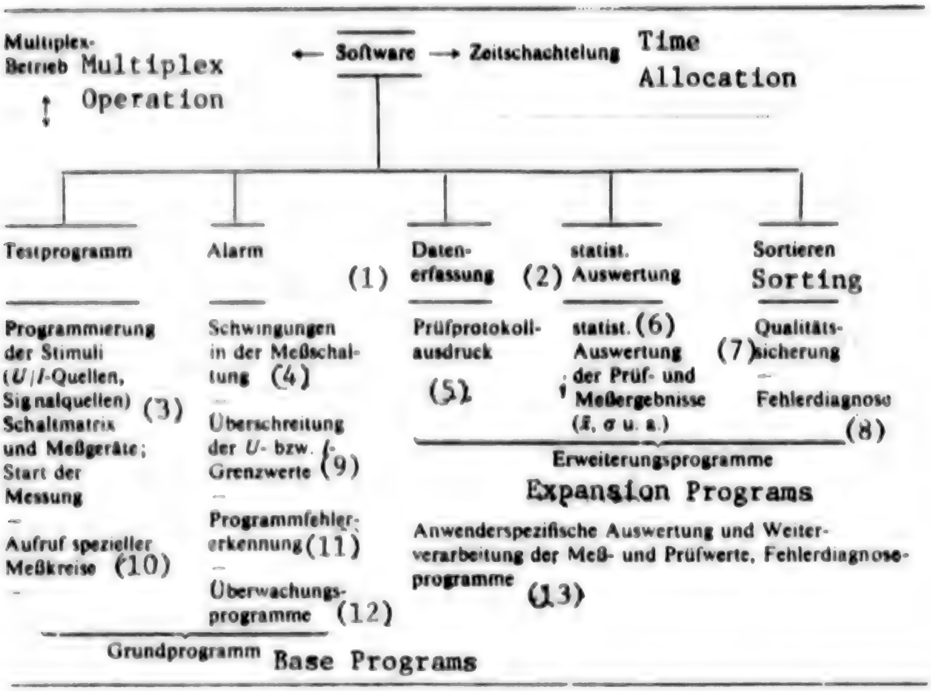


Figure 7. Microprocessor system (above: basic structure; below: basic computer unit).

Key:
1. Basic computer unit;
2. Memory expansion;
3. Input/output expansion;
4. Data bus;
5. Address bus;
6. Address decoder;
7. Control instruction;
8. Direction control.

Table 2

Overview of the Important Measurement and Test Data Acquisition and Processing Tasks


Multiplex-Betrieb Multiplex Operation
Software
Zeitschachtelung Time Allocation
Testprogramm
Alarm
(1)
Daten-erfassung
(2)
statist. Auswertung
Sortieren Sorting
Programmierung der Stimuli (U/I-Quellen, Signalquellen) Schaltmatrix und Meßgeräte; Start der Messung (3)
Aufruf spezieller Meßkreise (10)
Schwingungen in der Meßschaltung (4)
Überschreitung der U- bzw. I-Grenzwerte (9)
Programmfehlererkennung (11)
Überwachungsprogramme (12)
Prüfprotokollausdruck (5)
statist. (6) Auswertung der Prüf- und Meßergebnisse (x̄, σ u. a.)
(7) Qualitätssicherung
Fehlerdiagnose (8)
Erweiterungsprogramme
Expansion Programs
Anwenderspezifische Auswertung und Weiterverarbeitung der Meß- und Prüfwerte, Fehlerdiagnoseprogramme (13)
Grundprogramm Base Programs

Key:
1. Data acquisition;
2. Statistical evaluation;
3. Stimuli programming (V-I supplies, signal sources), switching matrix and measurement equipment; start of the measurement;
4. Oscillations in the measurement circuitry;
5. Test document printout;
6. Statistical evaluation of the test and measurement results ($\bar{x}$, σ, etc.);
7. Quality control;
8. Error diagnosis;
9. Exceeding the V or I limiting values;
10. Callup of special measurement circuits;
11. Program error recognition;
12. Supervisory program;
13. User specific evaluation and subsequent processing of the measurement and test data, error diagnosis programs.

Automatic Measurement and Test Technology

Automatic measurement and test technology encompasses the area of measurement technology which utilizes computer controlled equipment complexes to solve existing problems. In this case, the central control of individual,

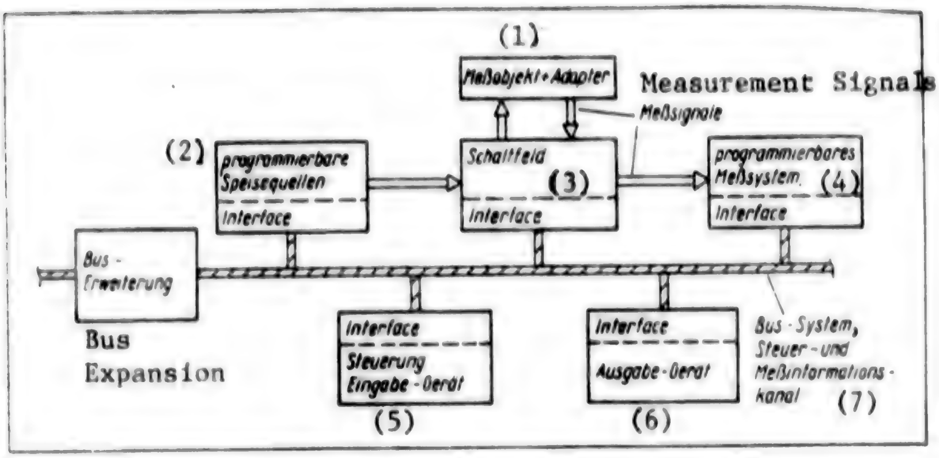


Figure 8. Basic structure of automatic measurement and test systems (controllable individual components interconnected via standardized buses).

Key:
1. Measurement object and adaptor;
2. Programmable power supplies;
3. Switching field;
4. Programmable measurement system;
5. Control, input unit;
6. Output unit;
7. Bus system, control and measurement data channel.

is relieved of various tasks in measurement data processing and measurement data evaluation through the realization of these tasks, and thereby is practically exclusively available for the process control of the entire system and the final measurement data processing. In this case, the performance of electronic measurement systems will substantially increase because of microprocessors, arithmetic processors, single chip computers and semiconductor memories, as well as with the increasing trend towards integration of software and hardware in a chip. Besides the well known methods of characteristic value computation (mean value, disperion, effective value, distortion factor, Fourier transformation, etc.), characteristic curve correction for measurement value transducers or automatic callibration, in a hardware sense additional measurement data processing routines [20], internal checking, and the changing of parameters, criteria and procedures will determine the functional scope of measurement systems in the case of inadequate or unsatisfactory results. The problems this entails are to be briefly treated in conclusion using the example of automated measurement and test equipment.

and at times intelligent equipment is typical of the majority of applications cases. Special results are achieved in the execution of scientific experiments and the solution of fabrication process problems. In line with this, automated measurement and test technology is realized to a very different extent, and at times, with very different equipment designs in the laboratory and in the testing field. It represents an important prerequisite for the assurance of efficient and high quality production for the manufacture of components and equipment. The scope of the tasks here, includes among other things, the incorporation of individual measurement quantities and functions [20]. The following can be cited as typical examples: components, circuit boards and equipment testing. System configurations such as shown in Figure 8 [21] are employed for these tasks (Table 2).

Automatic test units have the following tasks to perform in a computer controlled manner:

1. Passive Testing

The determination of faults in objects being tested, which when the operating voltages are applied, would lead to the following faults:

--Tests for contact between the test object and the automatic testing equipment;

--Test for conductor continuity;

--Test of critical components and integrated circuits (polarity, etc.);

2. Active Testing

--Functional testing with the application of the operating voltages and signals;

3. Fault Diagnosis

--Fault localization, determination of faulting components, where necessary through additional adaptation of the object under test.

Objests to be tested in practice exhibit, among other things, substantial measurement engineering limitations as regards the accessibility of their functional components and the signal lines. Extensive tests (100 to 500 in the case of printed circuit boards, and 5,000 to 10,000 in the case of complex integrated circuits), expensive measurement programs and evaluation routines are employed. So it is understandable that only using a further refined computer controlled measurement technology and with the improvement of the test oriented configuration of the continually increasingly complicated test objects can these problems be economically solved.

Concluding Remarks

From the comments on the state of the art and the developmental trends in measurement technology, a few salient conclusions can be drawn, which are important both for the field of measurement equipment manufacture and application as well as for its design:

--Interdisciplinary cooperation (electronics, systems theory, information processing, etc.) is the foundation for the design, production and application of modern high performance measurement equipment. The incorporation of information processing, special measurement strategy, autoalignment and self-monitoring in the tasks of the measurement systems, as well as the integration of subassemblies require appropriate knowledge from the designers and users as regards the theoretical principles which are applicable in this respect. The requirements for suitable further refinement measures follow from this.

--The modular concept, as well as the application of a standard interface to assure a problem free interconnection and unobjectionable interaction is to be realized in a thorough manner. Otherwise, the multiplicity of requisite system variants cannot be realized economically.

--Following a critical analysis of the measurement tasks, the design of the measurement equipment is to be based on functional units and discrete circuit designs are to be largely eliminated. The basis for this is the providing of an appropriate assortment of functional electronic components (counters, analog to digital and digital to analog converters, multiplexers, operational amplifiers, memories, arithmetic units, etc., in integrated technology).

The indicated trend towards curtailing the requisite production process steps in the manufacture of integrated functional units offers measurement technology the possibilities of also manufacturing their special circuit assemblies in the future, where these circuits are not required in large numbers. The corresponding design foundations are to be created for this.

--Besides a fabrication oriented design, testing during the fabrication process (a configuration amenable to testing), maintenance and reliability, as well as internal checking are of particular importance.

--The inclusion of microelectronics, optoelectronics, as well as magnetoelectronic principles assure the use of optimum operational principles for the solution of measurement technology problems. The integrated circuit technology base is to be further expanded in this direction in line with the trend outlined here.

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